CHAPTER 2. ANALYTICAL FRAMEWORK, COMMENTS FROM INTERESTED PARTIES, AND DEPARTMENT OF ENERGY RESPONSES

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 2. ANALYTICAL FRAMEWORK, COMMENTS FROM INTERESTED PARTIES, AND DEPARTMENT OF ENERGY RESPONSES

2.1 INTRODUCTION

The Energy Policy and Conservation Act (EPCA), as amended (42 USC 6291 et. seq.), requires that when prescribing new or amended energy conservation standards for covered products, the U.S. Department of Energy (DOE) must promulgate standards that achieve the maximum improvements in energy efficiency that are technologically feasible and economically justified. (42 U.S.C. 6295(o)(2)(A)) This chapter provides a description of the analytical framework that DOE is using to evaluate new energy conservation standards for residential furnace fans. This chapter sets forth the methodology, analytical tools, and relationships among the various analyses that are part of this rulemaking.

The analyses performed as part of the preliminary analysis stage and reported in this preliminary technical support document (TSD) are listed below.

- A market and technology assessment to characterize the relevant products, their markets, and technology options for improving their energy efficiency, including prototype designs.
- A screening analysis to review each technology option and determine if it is technologically feasible; is practicable to manufacture, install, and service; would adversely affect product utility or product availability; or would have adverse impacts on health and safety.
- An engineering analysis to develop relationships that show the manufacturer's cost of achieving increased efficiency.
- A markups analysis to develop distribution channel markups that relate the manufacturer production cost (MPC) to the cost to the consumer.
- An energy use analysis to determine the annual energy use of the considered products in a representative set of users.
- A life-cycle cost (LCC) and payback period (PBP) analysis to calculate the savings in operating costs at the consumer level throughout the life of the covered products compared with any increase in the installed cost for the products likely to result directly from imposition of a standard.
- A shipments analysis to forecast product shipments, which are then used to calculate the national impacts of standards on energy, net present value (NPV), and future manufacturer cash flows.
- A national impact analysis (NIA) to assess the aggregate impacts at the national level of potential energy conservation standards for the considered products, as measured by the NPV of total consumer economic impacts and the national energy savings (NES).

- A preliminary manufacturer impact analysis (MIA) to assess the potential impacts of energy conservation standards on manufacturers' capital conversion expenditures, marketing costs, shipments, and research and development costs.

In the subsequent Notice of Proposed Rulemaking (NOPR), DOE will present the tentative results of the above analyses, incorporating any revisions to the analyses based on comments and new information received. DOE will also present tentative results of the following additional analyses in the NOPR:

- A consumer subgroup analysis to evaluate variations in customer characteristics that might cause a standard to affect particular consumer sub-populations (such as low-income households) differently than the overall population.
- An MIA to estimate the financial impact of standards on manufacturers and to calculate impacts on competition, employment, and manufacturing capacity.
- An employment impact analysis to assess the aggregate impacts of the considered standards on national employment.
- A utility impact analysis to estimate selected effects of the considered standards on electric utilities.
- An emissions analysis to assess the effects of the considered standards on emissions of carbon dioxide (CO_2), nitrogen oxides (NO_x), and mercury (Hg).
- An emissions monetization that estimates the economic value of reductions in CO_2 and NO_X emissions from the considered standards.
- A regulatory impact analysis (RIA) to evaluate alternatives to amended energy conservation standards in order to assess whether such alternatives could achieve substantially the same regulatory goal at a lower cost.

2.2 BACKGROUND

EPCA grants DOE authority to consider and prescribe new energy conservation standards or energy use standards for electricity used for purposes of circulating air through duct work. . (42 U.S.C. 6295(f)(4)(D)) DOE interprets this statutory language to allow DOE to regulate the electricity use of any electrically-powered device used in residential central heating, ventilation, and air-conditioning (HVAC) systems for the purpose of circulating air through duct work.

DOE developed this analytical framework and documented its findings in the Rulemaking Framework for Furnace Fans (June 1, 2010). On June 3, 2010, DOE published the Notice of Public Meeting and Availability of the Framework Document for furnace fans in the *Federal Register*. 75 FR 31323. In conjunction, DOE posted the Framework Document to the

DOE website.[1] DOE presented the analytical approach to interested parties during a public meeting held on June 18, 2010.

In response to the publication of the Framework Document and the Framework public meeting, DOE received numerous comments from interested parties regarding DOE's analytical approach. This chapter (chapter 2) of the preliminary TSD summarizes the key comments DOE received from interested parties and presents DOE's responses to those comments. . In addition, in subsequent sections of this chapter, DOE has summarized any significant changes in analytical approach made since publishing the Framework Document that DOE used in its preliminary analyses. Lastly, in the Executive Summary of the preliminary TSD, DOE identified a number of issues on which DOE seeks public comment. DOE has explained each of those issues in the relevant analytical sections below.

2.2.1 Rulemaking Schedule

In the Framework Document, DOE stated that it would not be conducting a preliminary analysis for this rulemaking. Instead, DOE planned to use a straight-to-NOPR schedule to align with the publication dates of associated rulemakings for residential furnaces and boilers, and central air conditioners (CAC) and heat pumps.[2]

The Northeast Energy Efficiency Partnership (NEEP) and Adjuvant Consulting, Inc. (Adjuvant) urged DOE to conduct a preliminary analysis and publish a preliminary analysis TSD for this rulemaking. (NEEP, No. 16 at p. 2 and Adjuvant, No. 9 at p. 4)[3] NEEP added that DOE should publish the preliminary analysis TSD well in advance of the NOPR so that interested parties are able to carefully review the analysis DOE will use to propose efficiency levels. NEEP also urged DOE to accelerate the furnace fan rulemaking to align with the 2016 compliance dates of the associated rulemakings for residential furnaces and CAC. NEEP believes doing so would minimize disruptions to the industry and capitalize on an energy saving opportunity sooner. (NEEP, No. 16 at p. 2)

On January 15, 2010, interested parties submitted a joint comment to DOE's residential furnaces and central air conditioners and heat pumps rulemakings recommending adoption of a package of minimum energy conservation standards for residential central air conditioners, heat pumps, and furnaces, as well as associated compliance dates for such recommended standards (the "Consensus Agreement"). The Consensus Agreement represents a negotiated agreement

---

[1] The June 1, 2010 furnace fan Framework Document is available at the following link: http://www1.eere.energy.gov/buildings/appliance_standards/residential/furnace_fans_framework.html

[2] Information regarding the DOE rulemaking activities for residential furnaces and boilers, and residential central air conditioners and heat pumps is available at the following links, respectively: http://www1.eere.energy.gov/buildings/appliance_standards/residential/furnaces_boilers.html and http://www1.eere.energy.gov/buildings/appliance_standards/residential/residential_cac_hp.html

[3] A notation in this form provides a reference for information that is in the docket of DOE's rulemaking to develop energy conservation standards for furnace fans (Docket No. EERE-2010-BT-STD-0011), which is maintained at www.regulations.gov. This notation indicates that the statement preceding the reference is document number 16 in the docket for the energy conservation standards rulemaking for furnace fans, and appears at page 2 of that document.

among a variety of interested parties, including manufacturers and environmental and efficiency advocates. The original agreement was completed on October 13, 2009 and had 15 signatories. Upon receiving the Consensus Agreement and analyzing the recommended energy conservation standards contained in the agreement, DOE published a direct final rule amending the energy conservation standards for residential furnaces, central air conditioners, and heat pumps on June 27, 2011. 76 FR 37408. DOE simultaneously published a notice of proposed rulemaking, accepting public comments on the adopted standards until October 17, 2011. 76 FR 37549 (June 27, 2011). Upon consideration of the comments received, DOE published a final rule confirming the energy conservation standard levels adopted in the direct final rule as the Federal standard levels for residential furnaces and residential central air conditioners and heat pumps. 76 FR 67037 (Oct. 31, 2011). Compliance with the standards established in the final rule is required starting May 1, 2013 for non-weatherized furnaces, and January 1, 2015 for weatherized furnaces and central air conditioners and heat pumps.

The Consensus Agreement did not include recommended minimum energy conservation standards or compliance dates for furnace fans. Consequently, the original rulemaking schedules for the associated rulemakings changed, and DOE decided to set the furnace fan rulemaking schedule separately. Instead of coordinating with the rulemaking schedules of associated standards, DOE plans to complete this rulemaking by the statutory deadline outlined in EPCA, December 31, 2013. (42 U.S.C. 6295(f)(4)(D)) DOE decided that adherence to a rulemaking schedule that will meet the statutory deadline (December 31, 2013) provides adequate time to conduct a preliminary analysis. DOE agrees with interested parties that publication of a preliminary analysis TSD will provide DOE with the ability to further investigate the product and provide interested parties with additional opportunities to comment. Therefore, DOE conducted a preliminary analysis and is publishing this preliminary analysis TSD.

2.3 MARKET AND TECHNOLOGY ASSESSMENT

When DOE begins an energy conservation standards rulemaking, it develops information that provides an overall picture of the market for the products considered, including the nature of the products, market characteristics, and industry structure. This activity consists of both quantitative and qualitative efforts based primarily on publicly-available information. The market assessment examined manufacturers, trade associations, and the quantities and types of products offered for sale.

DOE recognizes that there may be limited public information on national shipments, manufacturing costs, channels of distribution, and manufacturer market shares of furnace fans. This type of data is an important input for analyses that determine if energy conservation standards are economically justified and will result in significant energy savings. Therefore, DOE encourages interested parties to submit data that will improve DOE's understanding of the furnace fan market. These data may be provided under a confidentiality agreement with DOE's contractor responsible for this part of the rulemaking analysis, Navigant Consulting, Inc. (NCI). In other rulemakings, NCI works with confidential data provided by manufacturers and other organizations in preparing aggregated results for DOE's analysis. These aggregated results do not divulge the sensitive, individual raw data, but enable other interested parties to comment on the aggregated dataset.

Alternatively, interested parties may submit confidential data to DOE, indicating in writing which data should remain confidential. Interested parties must submit confidential information to DOE according to the procedures outlined in 10 CFR 1004.11. Pursuant to 10 CFR 1004.11, any person submitting information that he or she believes to be confidential and exempt by law from public disclosure should submit two copies. One copy of the document shall include all the information believed to be confidential, and the other copy shall have the information believed to be confidential deleted. DOE will make its own determination about the confidential status of the information and treat it accordingly.[4]

DOE reviewed relevant literature and interviewed manufacturers to develop an overall picture of the residential furnace fan industry in the United States. Industry publications and trade journals, government agencies, and trade organizations provided the bulk of the information, including: (1) manufacturers and their market shares; (2) shipments by product type (*e.g.*, non-weatherized gas furnace, oil furnace, hydronic air-handler); (3) product information; and (4) industry trends. The analyses developed as part of the market and technology assessment are described in chapter 3 of the TSD.

2.3.1 Scope of Coverage

EPCA grants DOE authority to consider and prescribe new energy conservation standards or energy use standards for electricity used for purposes of circulating air through duct work. (42 U.S.C. 6295(f)(4)(D)) In the Framework Document, DOE tentatively interpreted this EPCA language to allow DOE to cover the electricity used by any electrically-powered device used in a residential, central HVAC system for the purpose of circulating air through duct work. Consequently, DOE tentatively defined a "residential furnace fan" as any electrically powered device used in a residential central HVAC system for the purpose of circulating air through duct work. DOE described a typical furnace fan as consisting of a fan motor and its controls, a centrifugal impeller, and sheet metal housing. DOE sought comment on including gas furnaces, oil furnaces, electric furnaces, CAC air handlers, and modular blowers in the scope of coverage. DOE also sought comment on excluding draft inducer fans, exhaust fans, heat recovery ventilators (HRV), and energy recovery ventilators (ERV) from the scope of coverage, because inducer fans do not circulate air through duct work, and these products were excluded from the scope of the December 2009 draft of Canadian Standard Association (CSA) C823, *Performance Standard for Air Handlers in Residential Space Conditioning Systems*. DOE also requested comment on whether other products, such as small-duct, high-velocity (SDHV) and through-the-wall systems should be included in the scope of coverage of this rulemaking.

[4] Factors that DOE considers when evaluating requests to treat submitted information as confidential include: (1) a description of the items; (2) whether and why such items are customarily treated as confidential within the industry; (3) whether the information is generally known by or available from other public sources; (4) whether the information has previously been made available to others without obligation concerning its confidentiality; (5) an explanation of the competitive injury to the submitting person which would result from public disclosure; (6) a date after which such information might lose its confidential character; and (7) why disclosure of the information would be contrary to the public interest.

Interested parties commented on the use of the term “furnace fan,” DOE’s tentative definition, and the list of components that constitute a furnace fan. The Northwest Energy Efficiency Alliance (NEEA) and Natural Resources Defense Council (NRDC) recommended that DOE use the term “air handler” instead of “furnace fan.” NRDC stated that the term “furnace fan” unnecessarily restricts the product category and could be confusing. (NEEA, No. 11 at pp. 1-2; NRDC, No. 28 at p. 2) NEEA and the American Council for an Energy Efficient Economy (ACEEE) added that the definition of “furnace fan” should include the HVAC product cabinet. (NEEA, No. 11 at pp. 1-2; ACEEE, No. 19 at p. 3) NRDC commented that DOE should not restrict the definition of “furnace fan” to a specific impeller type or material. (NRDC, No. 28 at p. 5) Regal Beloit agreed with NRDC, stating that the furnace fan description should allow for housings that are made of non-metal materials. (Regal Beloit No. 32 at p. 2)

DOE plans to use the term “furnace fan” to remain consistent with the Energy Independence and Security Act of 2007 (EISA 2007) language that amends EPCA to set the statutory deadline of December 31, 2013 for this rulemaking. In addition, DOE plans to use the definition presented in the Framework Document. DOE believes this definition clearly states that DOE does not plan to limit the scope of coverage of this rulemaking to circulation fans used in furnaces. DOE does not believe that the use of the term “air handler” will provide any additional clarity because air handlers can include electricity-consuming components other than the circulation fan, such as inducer fans and electric resistance heating coils. The electricity consumption of these other components is outside the scope of coverage of this rulemaking. DOE is aware that the airflow path design of the HVAC product cabinet impacts furnace fan performance. DOE accounted for these impacts in the proposed test procedure and in the preliminary analysis and plans to continue to account for these impacts in the NOPR. DOE is also aware that furnace fans can use different types of impellers, as well as a number of different materials for furnace fan components. Therefore, for the preliminary analysis, DOE did not limit the definition to specific impeller types or materials. DOE considered a typical furnace fan as consisting of a fan motor and its controls, an impeller, and a housing, all of which are components of an HVAC product that includes additional components, including the cabinet. Comments received and DOE’s approach regarding the scope of coverage are discussed in more detail in the following paragraphs.

Some interested parties disagreed with DOE’s approach in this rulemaking in terms of setting component-level regulations, as opposed to system-level regulations. Morrison and the Air-Conditioning, Heating and Refrigeration Institute (AHRI) commented that regulating a component (furnace fan) of a larger system (HVAC product) may lead to a suboptimal system. AHRI stated that standards set for entire systems are, therefore, more appropriate for achieving energy savings. (Morrison, No. 26 at p. 1; AHRI, No. 7 at p. 102) Ingersoll Rand agreed, stating that DOE should focus on systems, not components. (Ingersoll Rand, No. 7 at pp. 36-37) Rheem explained that furnace fans in higher-efficiency furnaces consume more electricity. According to Rheem, more "fan watts" are necessary to achieve turbulent flow, which increases heat transfer. Rheem added that the fan must also consume more electricity to overcome the added external static pressure (ESP) of more complex and additional condensing heat exchangers. Therefore, Rheem is concerned that regulating furnace fans separately, which ignores thermal performance, could be an issue. (Rheem, No. 7 at p. 112)

Other interested parties supported regulating components of larger systems. NEEP and Adjuvant stated that they support setting standards for components of systems that may be regulated by other standards, because furnace fans may be used in a large number of applications other than in furnaces and CAC. (NEEP, No. 16 at p. 2; Adjuvant, No. 7 at pp. 118-120) NEEP suggested DOE determine the prevalence of furnace fans in all central HVAC applications as part of its analysis for this rulemaking. NEEP added that, even though the seasonal energy efficiency ratio (SEER) metric accounts for energy used by the fan, the metric does not account for, or reward, gains in furnace fan efficiency. NEEP explains that a manufacturer could improve fan efficiency to meet a minimum SEER standard while ignoring opportunities to improve system efficiency through other components. NEEP believes a stand-alone furnace fan standard would ensure that higher SEER values are achieved by improving core functions not just the furnace fan. (NEEP, No. 16 at p. 2)

In response, DOE is required by EPCA to consider and prescribe new energy conservation standards or energy use standards for electricity used for purposes of circulating air through duct work. (42 U.S.C. 6295(f)(4)(D)) Pursuant to this statutory mandate, DOE plans to establish energy conservation standards for circulation fans used in residential central HVAC systems. DOE is aware that component-level regulations could have system-level impacts. DOE plans to conduct its analyses and set standards in such a way that meets the statutory requirements set forth by EPCA without ignoring system effects, which could possibly compromise the thermal performance of the HVAC products that incorporate furnace fans. For example, the proposed test procedure specifies that the furnace fan be tested while installed in the HVAC product, thereby enabling the rating metric to account for system effects on airflow delivery and, ultimately, energy performance. In addition, the product class structure allows for differentiation of products with higher thermal efficiency, such as condensing furnaces.

Many interested parties, including AHRI, Ingersoll Rand, Rheem, Lennox and Morrison, suggested that DOE limit the scope of coverage of the furnace fan rulemaking to distribution fans used in gas, oil, and electric furnaces. (AHRI, No. 20 at p. 7; Ingersoll Rand, No. 25 at p. 1; Rheem, No. 29 at p. 2; Lennox, No. 23 at p. 1; Morrison, No. 26 at p. 2) AHRI, Ingersoll Rand, and Morrison stated that the electrical consumption of fans used in split-system and packaged CAC and heat pump air handlers, modular blowers, SDHV systems and through-the-wall systems are already regulated through the use of the SEER and heating seasonal performance factor (HSPF) rating metrics. (AHRI, No. 20 at p. 2; Ingersoll Rand, No. 25 at p. 1; Morrison, No. 26 at p. 2) Rheem also echoed that the scope of coverage should not include split-system and packaged central air-conditioners and heat pump air handlers or modular fan coils. (Rheem, No. 29 at p. 1) AHRI commented that, conversely to the CAC standard metrics, the residential furnaces rating metric, annual fuel utilization efficiency (AFUE), only accounts for the gas and oil energy consumption of the furnace, and that the DOE test procedure for residential furnaces does not provide a mechanism to account for the electrical consumption or efficiency of the fan in the AFUE metric. AHRI added that the insertion of the statutory language under 42 U.S.C. 6295(f), titled "Standard for furnaces and boilers," indicates that the scope of the requirements outlined therein only pertains to motor and blower combinations used in residential, warm-air furnaces. According to AHRI, if the intent of the rulemaking is to include circulation fans used in CAC air handlers, then a corresponding paragraph should have been added in the statute titled "Standards for central air conditioners and heat pumps." (AHRI, No. 20 at p. 2) Further, Ingersoll Rand stated that including CAC air handlers in this rulemaking could lead to double counting of the energy consumption of the fans used in those products. (Ingersoll Rand, No. 7 at p. 26) AHRI also stated that this standard should not apply to the air-conditioning functions of the furnace fan. (AHRI, No. 7 at p. 118) Lennox stated that it supports AHRI's position regarding the scope of coverage of products. (Lennox, No. 23 at p. 1)

In contrast, other interested parties believe that fans used in non-furnace products should be included in the scope of coverage of this rulemaking. NEEP and the American Gas Association (AGA) expressed support of the tentative scope of coverage outlined in the Framework Document, which included circulation fans used in split-system and packaged CAC/heat pump products and modular blowers, in addition to circulation fans used in furnaces. (NEEP, No. 16 at p. 1; AGA, No. 14 at p. 1) AHRI commented that if modular fan coils are to be covered, then a corresponding change to the definition of "furnace," or the addition of a product class along with changes to the test procedure, are required. (AHRI, No. 20 at p. 2) ACEEE and AGA emphasized that electric air handlers/furnaces should be included in the scope of coverage. (ACEEE, No. 19 at p. 3) (AGA, No. 14 at p. 1) NEEA commented that air handlers that are part of heat pump systems, fossil fuel furnaces, electric furnaces, mobile home furnaces, and hydronic systems should be included. (NEEA, No. 24 at p. 2) NRDC stated that DOE should include all HVAC fans in the rulemaking to prevent confusion. (NRDC, No. 28 at p. 2) Based on the statutory language in EPCA, ACEEE strongly recommended that DOE not limit the scope of the standard to only furnaces. Instead, ACEEE suggested that DOE use the more descriptive term "residential air handler," as opposed to furnace fan. ACEEE added that industry shipment data suggest that 32% of residential air handlers are not furnaces, but serve heat pumps. According to ACEEE, RECS data suggest that 73% of single-family homes with forced-air heating have furnaces, with the rest divided between heat pumps and electric furnaces. Thus, ACEEE concluded that, although most fans are sold as components of furnaces, very substantial minorities are designed, built, sold, and installed in air handlers supporting heat pump and electric furnace installations. (ACEEE, No. 19 at pp. 1-2)

Adjuvant Consulting stated that hydronic air handlers, which incorporate a blower and hydronic heat exchanger supplied with hot and cold water, should also be covered. (Adjuvant, No. 9 at p. 5 and Public Meeting Trascript, No. 7 at pp. 38-39) NRDC agreed with Adjuvant and commented that it is DOE's responsibility to regulate hydronic air handlers. (NRDC, Public Meeting Transcript, No. 7 at pp. 43-44) Rheem agreed with Adjuvant that many air handlers are being used in hydronic systems, but hydronic air handlers should not be included in the rulemaking. (Rheem, No. 29 at p. 1) (Rheem, Public Meeting Transcript, No. 7 at pp. 35-36) AHRI commented that the hydronic system described by Adjuvant seems like a multi-family system and is not within the scope of this rulemaking. (AHRI, Public Meeting Transcript, No. 7 at p. 39) Mortex stated that hydronic systems are field application systems. Mortex stated further that it will be difficult to regulate custom systems, so only conventional systems should be regulated. (Mortex, Public Meeting Transcript, No. 7 at pp. 42-43)

ACEEE stated that the metrics adopted should exclude non-ducted central components, such as draft inducer fans, exhaust fans, HRVs, or ERVs. (ACEEE, No. 19 at p. 3) Rheem stated that it agrees with DOE in that ERVs, HRVs, and exhaust fans should not be covered in the furnace fan rulemaking. (Rheem, No. 29 at p. 2) AHRI and AGA also stated that the scope of coverage of this rulemaking should exclude draft inducer fans, exhaust fans, HRVs, and ERVs. (AHRI, Public Meeting Transcript, No. 7 at p. 29) (AGA, No. 14 at p. 1) Ingersoll Rand stated that neither draft inducer fans nor exhaust fans should be included in the rulemaking. (Ingersoll Rand, No. 25 at p. 1) Morrison commented that draft inducer fans should not be included because they do not circulate air through duct work. Morrison added that ERVs and HRVs should be excluded because they are not furnaces. (Morrison, No. 26 at p. 2)

Regal Beloit commented that the standard should apply to the total electrical consumption of the furnace fan product, which would include the consumption of other electrically-powered components such as draft inducer fans. Regal Beloit stated that ERVs, HRVs, SDHVs, and evaporative coolers should also be included in the scope of coverage. (Regal Beloit, No. 32 at p. 2) NRDC suggested that all motorized air-moving devices should be included in the scope of coverage, including draft inducers, exhaust fans, ERVs, and HRVs. (NRDC, No. 28 at p. 2)

DOE determined that, although the title of this statutory section refers to "furnaces and boilers," the provision was written using notably broader language than the other provisions within the same section. Consequently, DOE interprets this relevant statutory language to allow DOE to cover the electricity used by any electrically-powered device used in residential, central HVAC systems for the purpose of circulating air through duct work. Based on this interpretation, DOE does not agree with interested parties, such as AHRI, Ingersoll Rand, Rheem, Lennox, and Morrison, that the scope of coverage be limited to circulation fans used in furnaces. DOE recognizes that a significant number of products may fit its interpretation. DOE's preliminary approach is to address products for which DOE has sufficient data and information in this rulemaking. DOE may consider other such products in a future rulemaking, as data become available. For this rulemaking, DOE considered furnace fans used in products: (1) for which circulation fan energy consumption is not already covered in associated rulemakings; (2) for which sufficient data were available for its analyses; and (3) that could be tested using a similar test method (*i.e.*, setup and equipment, instruments and methods of measure, and range of operating conditions). The following list describes the furnace fans which DOE plans to address in this rulemaking.

- Products addressed in this rulemaking: furnace fans used in weatherized and non-weatherized gas furnaces, oil furnaces, electric furnaces, modular blowers, and hydronic air handlers
- Products not addressed in this rulemaking: other products that incorporate furnace fans, such as CAC blower-coil units, through-the-wall air handlers, SDHV air handlers, ERVs, HRVs, draft inducer fans, or exhaust fans

DOE is including hydronic air handlers because they compare favorably to other products based on the aforementioned criteria. In addition, DOE finds that HVAC product manufacturers do offer hydronic air handler models. Therefore, hydronics are not solely systems that are configured in the field as Mortex suggests. The products for which DOE is not considering standards in this rulemaking did not compare favorably to the included products based on the aforementioned criteria. However, the statutory language provides DOE the authority to regulate these products. Therefore, the aforementioned products that are not covered in this rulemaking may be considered in a future, separate rulemaking as data become available.

DOE is aware that the SEER and HSPF metrics that DOE uses to regulate residential CAC and heat pump (HP) products account for the indoor circulation fan's (*i.e*., furnace fan for the purposes of this rulemaking) electrical energy consumption during the cooling and heating seasons, respectively. For single packaged CAC/HP products, the circulation fan is integrated into the product, and, therefore, its energy consumption is measured during the certification testing for those products and then reflected in the calculated SEER/HSPF ratings. Similarly for split system CAC and heat pump products (*i.e.*, those that consist of separate indoor and outdoor units) where the indoor unit includes an integral blower (*i.e.*, a blower-coil unit), the SEER and, for heat pumps, the HSPF ratings account for that particular indoor fan's electrical energy consumption during the cooling and heating seasons. If the indoor unit of a split system, however, does not have a circulation fan (*i.e*., a coil-only unit), default values for a hypothetical indoor fan's power and heat generation are used to adjust the laboratory-measured capacities and power consumption values. These fan heat and power defaults are 1250 Btu/hr per 1000 CFM and 365 W / 1000 CFM, respectively. (10 CFR part 430, subpart B, appendix M, section 3.3.d) The SEER and HSPF for the coil-only unit are calculated using these fan-adjusted capacity and power values. Finally, manufacturers sometimes opt to certify a particular coil-only unit when paired with a specific model of furnace or modular blower – in effect converting a coil-ony unit to a blower-coil unit. In such cases, the SEER and HSPF ratings again are based on actual measurements of indoor circulation fan's electrical energy use. DOE expects that the largest population of certified ratings for CAC and heat pumps correspond to coil-only units whose SEER/HSPF ratings are based on the default values for the circulation fan's electrical consumption and heat dissipation. As a result, the electrical energy consumption of many indoor units that can be paired with coil-only units – such as non-weatherized furnaces, hydronic air handlers, and modular blowers – is not measured for certification. DOE is including residential CAC and heat pump products for this reason. Section 2.7 includes a discussion of how DOE avoids double-counting the energy savings in cooling mode from higher-efficiency furnace fans used in higher-efficiency CAC and heat pumps that is already accounted for in the analysis for standards on those products. During the July 2010 Framework Document public meeting, Adjuvant commented that DOE had recently published a small motors standard in February of that year and that some of the fan motors within the scope of the furnace fan rulemaking could already be included in that standard. (Adjuvant, Public Meeting Transcript, No. 7 at pp. 156-157) AHRI commented that motors used in HVAC systems are not regulated under the small motors rulemaking, and Morrison agreed. (AHRI, Public Meeting Transcript, No. 7 at p. 157; Morrison, Public Meeting Transcript, No. 7 at p. 174)

DOE does not expect any overlap in the scope of coverage of the small motors rulemaking and the furnace fans rulemaking. DOE agrees with interested parties that the capacitor start, capacitor run (CS/CR) and polyphase motors included in the scope of the small motors rulemaking are not typically used in residential applications.

In the Framework Document, DOE sought comment on coverage of the various modes of furnace fan operation (*i.e.*, active mode, standby mode, and off mode). DOE identified that active mode operation would be characterized by different rates of electrical consumption in each of a furnace fan's available airflow-control settings, each of which DOE expects are designated for a specific function (*i.e.*, cooling, heating, and constant circulation). DOE also stated in the Framework Document that it expected that furnace fans used in residential furnaces and CAC products will not have any standby mode electrical consumption that needs to be accounted for in this rulemaking, because electrical energy consumption in standby mode is already being addressed in the energy conservation standards rulemakings for these products. In addition, DOE stated that it did not expect furnace fans to have any off mode electrical energy consumption, as defined in the Framework Document, because most consumers are unlikely to set their residential, central HVAC systems to off mode. DOE proposed the following definitions for furnace fan "active mode," "standby mode," and "off mode" in the test procedure NOPR[5]:

- "Active mode" means any mode in which the HVAC product is connected to the power source and circulating air through duct work.
- "Off mode" means the mode during which the HVAC product is not powered.
- "Standby mode" means the mode during which the HVAC product is connected to the power source and the furnace fan is not activated.

These definitions are very similar to those presented in the Framework Document, but include slight modifications to be more consistent with definitions for "active mode," "standby mode," and "off mode" for the HVAC products in which furnace fans are used.

Interested parties commented that DOE should not include furnace fan electrical energy consumption in active mode that is already covered in other rulemakings. Ingersoll Rand stated that neither the energy use during cooling operation or heat pump heating operation should be included, because they are already included in the SEER and HSPF ratings. (Ingersoll Rand, No. 25 at p. 1) Lennox agreed, stating that the cost and energy of the furnace fan in cooling operation is included in the annual cooling energy and cost estimate required by DOE and Federal Trade Commission (FTC) regulations in the SEER metric. According to Lennox, the SEER metric includes measured fan performance for 89 percent of the active, split-system single-phase systems currently in the AHRI directory and 100 percent of single packaged units. Lennox added that a standard estimate for furnace performance is used for the remaining 11 percent of split-system listings that are not listed with a specific furnace and are known as "coil-only" units. (Lennox, No. 23 at p. 3) Rheem also commented that the furnace fans rulemaking should be limited to furnaces in the heating mode because, for matched systems with a furnace air handler, the energy use in cooling mode is already included in SEER. (Rheem, Public Meeting Transcript, No. 7 at pp. 26-27) Lennox stated that SEER is unlikely to increase as a result of a furnace fan standard. (Lennox, No. 23 at p. 3) Interested parties differed in support of considering operation in constant-circulation mode. Lennox commented that energy use for constant-circulation operation should not be included, because it is highly variable depending on a complex set of factors. Lennox concluded, therefore, that an estimate of average conditions for constant-circulation use would be of little or no value to consumers during the selection process. (Lennox, No. 23 at p. 3) Regal Beloit countered that the standard must account for constant-circulation use, because it is becoming more popular now that homes have tighter envelopes, which increases the need for ventilation. (Regal Beloit No. 32 at p. 2)

[5] U.S. Department of Energy-Office of Energy Efficiency and Renewable Energy, Energy Conservation Program for Consumer Products: Test Procedures for Furnace Fans, Notice of Proposed Rulemaking, May 17, 2012. Washington, DC. Federal Register / Vol. 77, No. 94.

After considering available information and public comments on this issue, DOE has decided to account for the electrical consumption of furnace fans while performing all active mode functions (*i.e.*, heating, cooling, and constant circulation) in its proposed rating metric. DOE recognizes that furnace fans are used not just for circulating air through duct work during heating operation, but also for circulating air during cooling and constant-circulation operation. DOE anticipates that higher airflow-control settings are factory set for cooling operation. Therefore, DOE expects that the electrical energy consumption of a furnace fan is generally higher while performing the cooling function. Additionally, the design of the fan as well as its typical operating characteristics (*i.e.*, ESP levels during operation in different modes) is a strong function of the performance requirements in cooling mode. Consequently, DOE expects that only accounting for electrical consumption in an airflow-control setting designated for heating in the rating metric could result in an incomplete assessment of overall performance. DOE further recognizes that the potential for significant power reduction occurs when the fan is operating in its lowest airflow-control setting, which DOE finds is typically factory set for constant circulation. This significant power reduction is consistent with the theory that fan input power is proportional to the cube of the airflow. Consequently, a "snapshot approach" that specifies only a single airflow-control setting may not be representative of the product's average use. However, some fan technologies may not reduce power input in this fashion. DOE is concerned that rating furnace fan performance at a single airflow-control setting would incentivize manufacturers to design fans that are optimized to perform efficiently at the selected rating airflow-control setting but that are not efficient over the broad range of field operating conditions. DOE expects that accounting for electrical consumption in multiple airflow-control settings in the rating metric will help ensure that the standard accounts for the efficiency advantages of using motor technologies that maintain higher efficiencies over a broad range of typical field operating conditions. DOE is aware that other technologies, such as improved impeller designs, may also improve efficiency in some of the expected range of operation.

The proposed rating metric accounts for fan electrical consumption while performing all active mode functions. Fan electrical consumption in the cooling mode is accounted for in the SEER metric that DOE uses for CAC and heat pump products, which means that the energy savings in cooling mode from higher-efficiency furnace fans used in some higher-efficiency CAC and heat pumps is already accounted for in the analysis of standards on those products. To avoid double-counting, the analysis for this rulemaking does not include furnace fan electricity savings that were already included in DOE's analysis for CAC and heat pump products. Section 2.7 of this chapter and chapter 8 of this TSD provide a discussion of this issue.

Many interested parties agreed with DOE that standby mode electrical energy consumption is sufficiently covered in other rulemakings and should not be included in this rulemaking. Rheem stated that only the active mode of operation should be addressed in this rulemaking because furnace fan standby consumption is covered by other rulemakings. (Rheem, No. 29 at p. 2 and Public Meeting Transcript, No. 7 at p. 46) According to Rheem, for example, assuming that the air handler or furnace is in standby mode if the system is not operating in heating, cooling, or circulating fan mode would result in double counting because standby is already addressed in the SEER calculation. (Rheem, No. 29 at p. 4) AHRI and Morrison commented that furnace fan standby is already accounted for in the DOE test procedures for furnaces (10 CFR Part 430, subpart B, Appendix N) and CAC and heat pumps (10 CFR Part 430, subpart B, Appendix M). (AHRI, No. 20 at p. 3; Morrison, No. 26 at p. 3) Ingersoll Rand stated that only active mode electrical energy consumption should be covered in this rulemaking, because standby should be counted for on a per appliance basis and not a per component basis. (Ingersoll Rand, No. 25 at p. 2) Lennox agreed that standby should be evaluated on the overall furnace rather than a component like the furnace fan. (Lennox, No. 23 at p. 4) Ingersoll Rand commented that it agreed with DOE's assumption that the standby power associated with a particular component (furnace fan) is already covered when the standby power of the system (furnace) of which that component is a part is covered in a separate standard. (Ingersoll Rand, Public Meeting Transcript, No. 7 at p. 33) Rheem added that electronically commutated motor (ECM) controls consume electrical energy when the impeller is not in motion, but this energy consumption is applicable to the furnace control system and should not be applied to the furnace fan if the part of the control is affixed to the motor housing. (Rheem, No. 29 at p. 2) NRDC agrees with DOE's definition of "standby mode" and stated that standby power has been estimated to consume about 10 percent of the electricity used in a gas furnace and should be regulated. (NRDC, No. 28 at p. 3) Adjuvant stated that, because furnace fans are used in products other than furnaces and CAC, some furnace fan standby consumption will go uncovered if DOE assumes that furnace fan standby consumption is fully covered by other associated rulemakings. (Adjuvant, Public Meeting Transcript, No. 7 at pp. 33-35)

Ingersoll Rand commented that off mode should not be included in this rulemaking. (Ingersoll Rand, No. 25 at p. 1) Ingersoll Rand did not provide any justification for its recommendation to exclude off mode electrical energy consumption.

EPCA, as amended by EISA 2007, requires that any final rule for a new or amended energy conservation standard adopted after July 1, 2010 must address standby mode and off mode energy use pursuant to 42 U.S.C. 6295(o). (42 U.S.C. 6295(gg)(3)) EISA 2007 also requires that such energy consumption be integrated into the overall energy efficiency, energy consumption, or other energy descriptor, unless the current test procedure already accounts for standby mode and off mode energy use. If an integrated metric is technically infeasible, DOE must prescribe a separate standby mode and off mode metric for the covered product. (42 U.S.C. 6295(gg)(2)(A))

Accordingly, DOE must address the standby mode and off mode energy use of residential furnace fans in this rulemaking. However, DOE has already incorporated standby mode and off mode energy use in energy conservation standards (or proposed energy conservation standards) for several of the products in the preliminary analysis scope of coverage. Measurement of standby mode and off mode energy use for non-weatherized gas furnaces, oil-fired furnaces, and electric furnaces is already prescribed in the DOE furnace test procedure (10 CFR part 430, subpart B, appendix N, section 8.0). In a September 13, 2011 NOPR, DOE proposed amendments to the furnace standby mode and off mode test procedure. 76 FR 56339. DOE proposed coverage of standby mode and off mode energy use for modular blowers and weatherized gas furnaces in a June 2, 2010 NOPR. 75 FR 31224, 31270. DOE subsequently published one SNOPR on April 1, 2011 and another on October 24, 2011 regarding standby mode and off mode test procedures for these products. 76 FR 18105; 76 FR 65616.

Furnace fans are integrated in the electrical systems of the HVAC products in which they are used and controlled by the main control board. Therefore, there is no standby mode and off mode energy use associated with furnace fans used in the aforementioned products that would not already be measured by the established or proposed test procedures associated with these products. Hence, given that the standby mode and off mode energy consumption of these types of furnace fans either has been or is in the process of being fully addressed, there is no need for DOE to establish standards for these modes for these products in this rulemaking.

However, there are no current energy conservation standards for electrical energy use in hydronic air handlers nor is there an ongoing rulemaking for which such test procedures have been proposed. Hence, the standby mode and off mode energy use for furnace fans that are incorporated into these products must be considered in this rulemaking pursuant to EPCA. In the furnace fan test procedure NOPR, DOE proposed to incorporate test methods to measure the standby mode and off mode energy of hydronic air handlers that are identical to those specified in the DOE test procedure for residential furnaces and boilers (10 CFR part 430, subpart B, appendix N, section 8.6). 77 FR 28674, 28689 (May 15, 2012). DOE proposed to also adopt the updates proposed in the September 13, 2011 furnaces test procedure NOPR (75 FR 56339) for measurement of standby mode and off mode energy of furnace fans incorporated in hydronic air handlers. DOE proposed to establish an integrated metric that combines the steady-state standby mode and off mode electrical energy consumption measurements for hydronic air handlers with the active mode energy use for these furnace fans, as required by EPCA. DOE proposes to weight the standby mode and off mode measurements by estimated national average hours for these modes. The hours associated with these modes are discussed in section III.D of the test procedure NOPR. Similar to furnaces, DOE expects that hydronic air handlers are not typically equipped with a seasonal off switch and that consumers would not turn off power to the hydronic air handler. Therefore, DOE estimates that electrical off mode consumption and the annual off mode operating hours will both be equal to zero.

AHRI commented that DOE should focus on regulating duct work to reduce the higher than recommended ESP that furnace fan products must face when installed. (AHRI, Public Meeting Transcript, No. 7 at p. 93)

While DOE shares the concerns about the negative impacts that poor duct work can have on furnace fan performance, DOE does not have statutory authority to regulate duct work.

2.3.2 Product Classes

When evaluating and establishing energy conservation standards, DOE generally divides covered products into product classes by the type of energy used, capacity, or other performance-related features that affect efficiency. Different energy conservation standards may apply to different product classes. (42 U.S.C. 6295(q)). DOE then conducts its analysis and considers establishing standards to provide separate standard levels for each product class.

In the Framework Document, DOE sought comment on differentiating between product classes based on rated airflow capacity or rated horse power. DOE sought comment on a range of rated airflow capacity from 400 to 2,200 cfm and a range of rated horsepower from 1/5hp to 1hp, based on an initial review of furnace fan product specification sheets. DOE planned to establish product classes by dividing the typical range of either rated airflow capacity or rated horsepower into bins based on market data and product characteristics. DOE also sought comment on the appropriate number or range of bins (*i.e.*, classes).

Morrison and AHRI stated that neither rated airflow capacity nor rated horsepower should be used because they are not certified descriptors and are not used as performance descriptors for residential products. (Morrison, No. 26 at p. 2; AHRI, No. 20 at p. 3) Rheem commented that it agreed that 400 to 2,200 cfm is an appropriate rated airflow capacity range for residential furnace fans. However, Rheem stated that rated airflow capacity should not be used as a furnace fan descriptor. (Rheem, No. 29 at p. 11) Rheem added that rated horsepower range applies to motor design and does not account for aerodynamic design of the fan or the internal static pressure. Therefore, according to Rheem, the horsepower of the product should not be used. (Rheem, Public Meeting Transcript, No. 7 at p. 31; Rheem, No. 29 at p. 2) Johnson Controls echoed Rheem's comment, stating that product classes should be based on rated airflow, not motor horsepower. (Johnson, Public Meeting Transcript, No. 7 at pp. 135-137) Morrison claimed that nameplate horsepower is an unreliable value on which to base motor comparisons. (Morrison, Public Meeting Transcript, No. 7 at p. 138) ACEEE commented that it strongly opposes the use of motor horsepower to define furnace fan product classes, because horsepower is an input. (ACEEE, No. 19 at p. 5) Regal Beloit suggested that DOE should define product classes based on CFM versus horsepower. According to Regal Beloit, the motor horsepower is only one factor in the system equation. Regal Beloit stated that some blowers are less efficient and would, thus, require a higher horsepower motor to drive the blower. Regal Beloit concluded that the critical variable that furnace and air handler manufacturers are looking for is the ability to drive a certain amount of airflow. (Regal Beloit, No.32 at p. 4)

Some interested parties, including Rheem, ACEEE, and Ingersoll Rand, commented on using heating/cooling capacity to differentiate product classes. Rheem commented that classifying furnace fans as either three-ton or five-ton units might be an appropriate method to define product classes. (Rheem, No. 29 at pp. 11-12) Rheem added that furnaces, air handlers, and package equipment are currently assigned product classes based on heating and cooling capacity. (Rheem, No. 29 at p. 11) ACEEE commented that documentation shows that manufacturers commonly ship condensing furnaces with alternative regional air handlers, with higher fan capacity relative to furnace output for furnaces meant for southern applications than those intended for northern sales. ACEEE stated that complications like these suggest that furnace capacity, like motor horsepower, is an inappropriate basis for separate product classes. (ACEEE, No. 19 at p. 3) Morrison commented that the energy consumed by a furnace fan product to meet certain cooling/heating demands would vary by manufacturer because specified cubic feet per minute (CFM) varies by capacity. (Morrison, Public Meeting Transcript, No. 7 at p. 96) Ingersoll Rand commented that furnace fans are selected based on heating and cooling capacity. Therefore, product classes should be developed along the lines of the furnaces that employ those furnace fans. (Ingersoll Rand, No. 25 at p. 3)

Other interested parties suggested that DOE should separate products into product classes by product application or internal design. Morrison and Johnson Controls stated that different furnace fan assemblies are used in different HVAC products. (Morrison, Public Meeting Transcript, No. 7 at p. 138; Johnson Controls, Public Meeting Transcript, No. 7 at p. 138) Rheem commented that categorizing the electrical consumption of furnace fans is impossible until the HVAC product is applied to a system. (Rheem, No. 29 at p. 12) Adjuvant stated that manufactured homes should be used to define a separate product class. (Adjuvant, No. 9 at p. 6)

Adjuvant also added that the manufactured home market is made unique by certain space and regulatory constraints. Adjuvant suggested that DOE should remain aware of, and account for, these unique concerns. (Adjuvant, Public Meeting Transcript, No. 7 at p. 132) NRDC stated that the products within the scope of the rulemaking have varying internal static pressure due to each type of heat exchanger and velocity across that heat exchanger associated with that particular product. NRDC also commented that internal and reference external static pressure be tied to the particular product class in which they are associated with to avoid particular products seeming better than others. (NRDC, No. 28 at p. 5) Johnson Controls also stated that manufactured homes, condensing furnaces, and non-condensing furnaces should each have separate product classes. (Johnson, Public Meeting Transcript, No. 7 at pp. 135-137) ACEEE commented that product classification by application, as indicated by the internal static pressure (*i.e.*, pressure drop across the heat exchanger) may be necessary. This approach would group technologies (within capacities) that have similar air handler requirements. (ACEEE, No. 19 at p. 3) Rheem stated that in a comparison of two furnaces, a condensing furnace and a non-condensing furnace with similar output capacity, the fuel consumption for the condensing furnace is less than the non-condensing furnace and the electrical consumption for the condensing furnace is greater than the non-condensing furnace. (Rheem, No. 29 at p. 9) Rheem also stated that, as the heat exchanger surface has increased with higher-efficiency equipment, the equipment has grown in volume and weight. (Rheem, No. 29 at p. 15) Ingersoll Rand commented that coil sizes have increased with higher SEER requirements while furnaces have gotten smaller. Ingersoll Rand claims that this trend makes it harder to maintain fan efficiency, because the same airflow has to be forced through a smaller unit. (Ingersoll Rand, Public Meeting Transcript, No. 7 at p. 133)

For the reasons stated by interested parties, DOE agrees that rated airflow capacity and rated horsepower are inappropriate for differentiating between product classes. These descriptors do not account for many of the factors that impact furnace fan performance, such as internal static pressure. In addition, DOE expects that the energy consumption impacts of heating/cooling capacity and airflow capacity are addressed by the rating metric proposed in the test procedure NOPR, fan efficiency rating (FER). The proposed rating metric is normalized by the airflow in the maximum airflow control setting, which is generally determined by the cooling capacity. Therefore, for the preliminary analysis, DOE decided to differentiate product classes for furnace fans based on application and internal structure, which are performance-related features that have a significant impact on energy efficiency. The application of the HVAC product dictates the external static pressure and, to a certain degree, the internal static pressure. For example, a manufactured home system will likely have a lower external static pressure than a site-built system and, as a result, consume less energy, all else being equal. A detailed discussion and field data to support this assumption are provided in the furnace fan test procedure discussion regarding proposed reference system external static pressure values. The internal structure (*i.e.*, geometry and configuration of components in the airflow path) determines the internal static pressure. For example, the geometry of a hydronic heat exchanger is different than the geometry of a clamshell heat exchanger, a furnace heat exchanger design typically found in non-weatherized gas furnaces, resulting in different internal static pressure levels and different expected energy consumption levels.

Based on application and internal static pressure, DOE identified 21 product classes for this rulemaking. The product classes identified for this rulemaking are listed below. DOE divided these product classes into nine key product classes and 12 additional product classes. Key product classes are those for which DOE is aware of significant shipments. Therefore, enough public data were readily available to conduct robust analyses. The additional product classes represent significantly fewer shipments and significantly less energy use. For the preliminary analysis, DOE grouped each non-key product class with a key product class to which it is closely related in application and internal structure (*i.e.*, the primary criteria used to differentiate between product classes). DOE assigned the analytical results of each key product class to the non-key product classes with which it is grouped. Table 2.3.1 presents the 21 product classes and maps the additional product classes to the nine key product classes.

Table 2.3.1: Product Classes

<table>
<tr><th>Key Product Class</th><th>Additional Product Classes</th></tr>
<tr><td>Non-Weatherized, Non-Condensing Gas Furnace Fan (NWG-NC)</td><td></td></tr>
<tr><td>Non-weatherized, Condensing Gas Furnace Fan (NWG-C)</td><td></td></tr>
<tr><td rowspan="5">Weatherized Gas Furnace Fan (WG-NC)</td><td>Weatherized, Non-Condensing Oil Furnace Fan (WO-NC)</td></tr>
<tr><td>Weatherized Electric Furnace/Modular Blower Fan (WEF/WMB)</td></tr>
<tr><td>Manufactured Home Weatherized Gas Furnace Fan (MH-WG)</td></tr>
<tr><td>Manufactured Home Weatherized Oil Furnace Fan (MH-WO)</td></tr>
<tr><td>Manufactured Home Weatherized Electric Furnace/Modular Blower Fan (MH-WEF/WMB)</td></tr>
<tr><td rowspan="2">Non-weatherized Oil, Non-Condensing Furnace Fan (NWO-NC)</td><td>Non-Weatherized, Condensing Oil Furnace Fan (NWO-C)</td></tr>
<tr><td>Manufactured Home Non-Weatherized Oil Furnace Fan (MH-NWO)</td></tr>
<tr><td>Non-weatherized Electric Furnace / Modular Blower Fan (NWEF/NWMB)</td><td></td></tr>
<tr><td rowspan="5">Heat/Cool Hydronic Air Handler Fan (HAH-HC)</td><td>Heat-Only Hydronic Air Handler Fan (HAH-H)</td></tr>
<tr><td>Hydronic Air Handler Fan with Coil (HAH-C)</td></tr>
<tr><td>Manufactured Home Heat/Cool Hydronic Air Handler Fan (MH-HAH-HC)</td></tr>
<tr><td>Manufactured Home Heat-Only Hydronic Air Handler Fan (MH-HAH-H)</td></tr>
<tr><td>Manufactured Home Hydronic Air Handler Fan with Coil (MH-HAH-C)</td></tr>
<tr><td>Manufactured Home Non-Weatherized Gas, Non-Condensing Furnace Fan (MH-NWG-NC)</td><td></td></tr>
<tr><td>Manufactured Home Non-Weatherized Gas, Condensing Furnace Fan (MH-NWG-C)</td><td></td></tr>
<tr><td>Manufactured Home Electric Furnace/ Modular Blower Fan (MH-EF/MB)</td><td></td></tr>
</table>

Each product class title includes descriptors that indicate the application and internal structure of its included products. Weatherized and non-weatherized are descriptors that indicate whether the HVAC product is installed outdoors or indoors, respectively. Weatherized products also include an internal evaporator coil, while non-weatherized products are not shipped with an evaporator coil but may be designed to be paired with one. Condensing refers to the presence of a secondary, condensing heat exchanger in addition to the primary combustion heat exchanger in certain furnaces. Manufactured home products meet certain design requirements that allow them to be installed in manufactured homes. Details regarding these design requirements are included in Chapter 3 of this TSD. Descriptors like gas, oil, electric or hydronic indicate the type of fuel or working fluid that the HVAC product uses to produce heat, which determines the type and geometry of the primary heat exchanger used in the HVAC product. Hydronic products include parenthetical descriptors to indicate whether the product is designed to be used for heating and cooling or heat only, as well as whether the product includes an internal evaporator coil.

2.3.3 Market Assessment

As part of the market and technology assessment, DOE developed information that provides an overall picture of the market for the products considered, including the nature of the products, market characteristics, and industry structure. DOE collected quantitative and qualitative information, primarily from publicly-available sources. The market assessment examined manufacturers, trade associations, and the quantities and types of products sold and offered for sale. DOE reviewed relevant literature and interviewed manufacturers to develop an overall picture of the residential furnace fan industry in the United States. Industry publications and trade journals, government agencies, and trade organizations provided the bulk of the information, including: (1) manufacturers and their market shares; (2) shipments by product type (*e.g.*, non-weatherized gas furnace, oil furnace, hydronic air-handler); (3) product information; and (4) industry trends. The analyses developed as part of the market assessment are described in chapter 3 of the TSD.

In the Framework Document, DOE sought comment on whether the manufacturers of products containing furnace fans are also the manufacturers of the furnace fans themselves. DOE also welcomed input on estimates of market shares, products, features, and trends related to electricity consumption for the furnace fans covered in this rulemaking and the HVAC products in which they are incorporated.

Some interested parties, including Ingersoll Rand, Rheem, Morrison, AHRI, and Johnson Controls, commented regarding the correlation between the manufacturers of furnace fans and those of HVAC products. Ingersoll Rand stated that furnace manufacturers are not normally the manufacturers of blower wheels or motors, but they may manufacture the blower housings used in their products. (Ingersoll Rand, No. 25 at p. 3) AHRI stated that manufacturers of furnace fans are sometimes the manufacturer of the products that utilize those fans, but it varies from manufacturer to manufacturer. AHRI also stated that some components are purchased, while others are fabricated. (AHRI, No. 20 at p. 7) Morrison echoed AHRI's comments, stating that the choice of whether to produce or purchase the furnace fan varies by manufacturer; some components are fabricated, and some are purchased. (Morrison, No. 26 at p. 6) Rheem stated that it manufactures furnace fans as a component of an air handler, furnace, or package unit. Rheem also purchases or has purchased subassemblies from vendors for incorporation into

Rheem products. (Rheem, No. 29 at p. 11) More specifically, Rheem has purchased fan kits from Morrison and Lau/Ruskin. The kits included the housing and wheel, and Rheem added the motor to the assembly. (Rheem, No. 29 at p. 11) Rheem stated that it sometimes manufactures the housing, as well. (Rheem, Public Meeting Transcript, No. 7 at p. 126) Ingersoll Rand commented that housings typically differ across manufacturers, because many of them make their own. Ingersoll Rand added that housings are sometimes purchased. (Ingersoll Rand, Public Meeting Transcript, No. 7 at p. 129) Regal Beloit stated that there are manufacturers who make all of the components of the furnace fan assembly (including the electric motor) that compete in the same space as the furnace/air handler manufacturer who manufacture some components of the furnace fan assembly, but still rely on outside companies to manufacturer electric motors. (Regal Beloit, No. 32 at p. 4) Johnson Controls stated that there are blower kits for manufactured home applications that can be installed in a competitor's product, in which case it is designed for a specific application, not product. (Johnson, Public Meeting Transcript, No. 7 at pp. 129-130) Rheem added that furnace fans are only sold separately as replacement parts. (Rheem, No. 29 at p. 15) Rheem also stated that the ECMs it offers in its equipment are programmed on the production line, and replacement motors must be programmed to match the original motor program. (Rheem, No. 29 at p. 16) AHRI stated that, ultimately, the burden of testing and certifying furnace fans will fall on the manufacturer of the product in which the furnace fan is incorporated. (AHRI, Public Meeting Transcript, No. 7 at p. 128)

DOE agrees with AHRI that the burden of meeting this standard falls on the manufacturer of the HVAC product in which the furnace fan is incorporated. DOE is aware that HVAC product manufacturers purchase many of the components in the furnace fan assembly, such as the motor and impeller, from separate component manufacturers. However, the HVAC product manufacturer determines the design requirements, selects the purchased components based on these requirements, and performs the final assembly and integration of the fan assembly into the HVAC product. Even in the less prevalent cases in which the HVAC product manufacturer purchases entire fan assemblies (including motor), the HVAC product manufacturer must integrate the assembly into the final product. The task of integrating the fan assembly could include programming the controls, as Rheem points out, which impacts the energy performance of the furnace fan. For these reasons, DOE’s estimates of manufacturer production costs generated for the preliminary analysis reflect the estimated costs to the HVAC product manufacturer to manufacture the furnace fan assembly and build it into the HVAC product. These costs take into account any component original equipment manufacturer (OEM) markup that the HVAC product manufacturer will incur when purchasing furnace fan parts.

A few interested parties, including Johnson Controls, Mortex, Rheem, and AHRI, commented on the market share of different furnace fan types. Johnson Controls stated that the Framework Document's estimate that 95 percent of furnaces use PSC motors may be incorrect, because Federal tax credits, utility rebates, weatherization programs, and energy efficiency standards have resulted in a recent increase in brushless permanent magnet, also referred to as ECM, motor implementation. Johnson Controls added that ECMs are not used in the majority of products yet, but the market is heading in that direction. (Johnson, Public Meeting Transcript, No. 7 at p. 142) Rheem echoed Johnson Controls’ comment, stating that the market share for ECMs rose from 10 percent to 30 percent within the last five years due to rebates associated with ECM motors. (Rheem, No. 29 at p. 3) Rheem also noted a report by the State of Wisconsin, Public Service Commission of Wisconsin Focus on Energy Evaluation Semiannual Report (18 month Contract Period).[6] In that time, ECM furnaces market share was reported to be 28 percent in the first quarter of 2008. Additionally, Federal tax, State, and utility rebates continue to increase the market share of Regal Beloit's constant-torque ECM line, the Genteq X13. (Rheem, No. 29 at p. 11) Johnson Controls added that, among all products containing furnace fans (air handlers and furnaces), ECMs account for 15 to 35 percent of the market, depending on the product family and manufacturer. (Johnson, Public Meeting Transcript, No. 7 at p. 144) Mortex added that, because of the decrease in the cost gap between ECM and PSC motors, there might not be any PSC motors on the market in 10 years or once the standard becomes effective. (Mortex, Public Meeting Transcript, No. 7 at pp. 143-144) Also, this decrease in supply and increase in demand could drive up prices for consumers. (Rheem, No. 29 at p. 16)

DOE acknowledges the comments received on PSC and ECM market shares. Based on available data and comments received, DOE believes that the market share for ECMs is approximately 30 percent. DOE recognizes that the ECM market share is in part due to rebates and tax credits associated with using this technology. Chapter 3 of this TSD includes a detailed description of past and existing rebates and tax credits for furnace fans.

AHRI suggested that DOE should solicit manufacturers on estimated market share, products, features, and trends related to electricity consumption for furnace fans covered by this rulemaking. (AHRI, No. 20 at pp. 7-8) DOE solicited the aforementioned information during interviews with manufacturers, which DOE conducted as part of the preliminary manufacturer impact analysis. More details regarding these interviews and their results are presented in chapter 12 of this TSD.

2.3.4 Technology Assessment

As part of the market and technology assessment, DOE developed a list of technologies to consider for improving the efficiency of furnace fans. Then, DOE removed technologies that do not change or affect the energy efficiency of furnace fans, as measured by the relevant metric in the DOE test procedures. Chapter 3 of the TSD includes the detailed list of all technology options DOE identified for further consideration in this rulemaking. DOE sought comment on the preliminary technology options identified in the Framework Document (*i.e.*, high-efficiency furnace fan motors and high-efficiency impellers) and whether there are other technology options DOE should consider.

ACEEE commented that DOE needs to consider foreign products in its analysis and the impacts that a DOE rulemaking will have on manufacturers' international production. ACEEE also commented that the "max-tech" analysis should include furnace fan technology not commonly available in the U.S. market. According to ACEEE, a comprehensive look at the entire furnace fan market must be analyzed. (ACEEE, No. 19 at p. 5)

---

[6] State of Wisconsin, Public Service Commission of Wisconsin Focus on Energy Evaluation Semiannual Report (18-month Contract Period) is accessible using the following link: http://www.cee1.org/eval/lighting_files/WisconsinFOE-2009-04-08.pdf

Some interested parties, including ACEEE, NEEA, NEEP, and Adjuvant, commented on how the airflow path design of the HVAC product affects furnace fan performance. ACEEE commented that manufacturers face market pressure to make cabinets as compact as possible, which leads to strong temptations to minimize clearances between the fan itself and the cabinet walls. This restricts airflow and reduces efficiency. (ACEEE, No. 19 at p. 2) ACEEE also stated that DOE has excluded important options pertaining to the air handler cabinet with their current definition of "furnace fan." These options include the clearance between the furnace fan and cabinet and aerodynamic couplings between the filter exit and a single-ended fan. (ACEEE, No. 19 at p. 5) NEEA stated that the airflow through the air handler cabinet is impacted by both the geometry of the airflow path and also the design of the heat transfer elements associated with the air handler. (NEEA, No. 11 at p. 2) Both NEEP and Adjuvant commented that DOE should include airflow path design as a third technology option category, because it impacts the ESP of the system and has potential to save energy. (NEEP, No. 16 at p. 4; Adjuvant, Public Meeting Transcript, No. 7 at p. 155)

DOE recognizes that the airflow path design of the HVAC product in which the furnace fan is used impacts efficiency. DOE also recognizes that alterations to the design and configuration of internal components, such as the heat exchanger, could impact the thermal performance of the HVAC product. DOE plans to conduct its analyses carefully to ensure that tradeoffs between airflow performance and thermal performance are well understood and do not result in reduced system efficiency. While DOE did account for the impacts of airflow path design in the proposed test procedure and other aspects of the preliminary analyses (*e.g.*, product class selection), DOE did not consider airflow path design as a technology option. DOE anticipates that the size of the cabinet and the geometry of the heat exchanger(s) would be the primary considerations. DOE did not include modeled cost and efficiency data for modifications to the cabinet size or heat exchanger geometry. DOE expects that a model that could ensure that overall system efficiency does not diminish due to tradeoffs between airflow efficiency and thermal efficiency would be overly complex. In addition, DOE expects that the costs for these improvements could be extremely high and result in little airflow efficiency improvement compared to the other technology options mentioned in this TSD. For a detailed discussion of the engineering analysis methodology, refer to chapter 5 of this TSD.

A few interested parties, including Rheem, Ingersoll Rand, and ACEEE, commented on the impellers used in furnace fan assemblies. Regal Beloit commented that furnace fans use both forward-curved and backward-curved impellers. (Regal Beloit No. 32 at p. 2) Rheem stated that there has been some work done on backward-curved impellers, but, currently, there are no backward-inclined impellers used in residential furnace fans, because they need larger diameters and higher revolutions-per-minute (RPMs). According to Rheem, backward-curved impellers have only proven to be effective in higher-capacity (10-ton) units as a result. Rheem stated that forward-curved fans have been demonstrated to provide the best performance in terms of capacity and efficiency for the airflow applications discussed in this rule. (Rheem, No. 29 at p. 13; Rheem, Public Meeting Transcript, No. 7 at pp. 154-155) Ingersoll Rand stated that impellers are very similar across products and manufacturers, with differences typically only in width and diameter. Ingersoll Rand added that impellers are chosen based on stability, breadth of operating conditions, loose tolerances, and ability to run at RPMs that best fit the application.

(Ingersoll Rand, Public Meeting Transcript, No. 7 at pp. 128-129) ACEEE commented that alternative air handler fans should be considered in the rulemaking. These different fans include cast aluminum or polymer impellers, as well as backward-curved impellers. (ACEEE, No. 19 at p. 5)

DOE was unable to find a commercially-available residential HVAC product that incorporates a backward-curved impeller. However, DOE is aware of research performed at national laboratories that includes testing of a prototype residential furnace that includes a backward-curved impeller. The results of these tests show that backward-curved impellers have the potential to improve furnace fan efficiency, albeit not as a simple drop-in solution and not across the entire range of expected operation for residential applications.[7] According to feedback from manufacturers, the efficiency improvement of backward-curved impellers may be much lower than preliminary research suggests, and there are a number of technical issues and design constraints associated with backward-curved impellers. Therefore, DOE is including backward-curved impellers as a technology option for the preliminary analysis with an estimated efficiency improvement of 10 percent, but expects to further review its estimates for cost and efficiency based on comments received for this preliminary analysis. Detailed discussions regarding the backward-curved impeller technology and how DOE is including them in the preliminary analysis can be found in chapters 3 and 5 of this TSD.

Some interested parties, including ACEEE, NRDC, Ingersoll Rand, Rheem, AHRI, Morrison, Johnson Controls, and Mortex, commented on the motors used in furnace fan assemblies. Ingersoll Rand stated that there are two principal motor technologies: (1) PSC motors and (2) ECMs. A motor is selected based on cost/performance analysis and the performance and feature set required of the product. There are no safety or consumer utility differences. (Ingersoll Rand, No. 25 at pp. 3-4) Ingersoll Rand also stated that manufacturers select motors that achieve specified speed-torque curves and desired airflow. (Ingersoll Rand, Public Meeting Transcript, No. 7 at pp. 129-131) To create a speed-torque curve, Ingersoll Rand first determines the amount of airflow needed at specified static pressures to select the width and diameter. Then, Ingersoll Rand determines the torque required to stay within normal operating conditions. The result is the speed-torque curve needed to select the motor. (Ingersoll Rand, Public Meeting Transcript, No. 7 at p. 131) Ingersoll Rand stated that, if there is too much pressure drop, the ECM will ramp up power use and then level off to protect the motor from drawing too many amps. Ingersoll Rand added that the goal is to install a furnace that can achieve the necessary temperature rise for safety reasons. (Ingersoll Rand, Public Meeting Transcript, No. 7 at pp. 149-150) Mortex echoed Ingersoll Rand, stating that safe operation is dependent on airflow in furnaces and air handlers with strip heating, so safe operation also factors into furnace fan design decisions. (Mortex, Public Meeting Transcript, No. 7 at p. 144) Morrison stated that ECMs have built-in protection and have power-limiting features to prevent the motor from going past certain power draws. (Morrison, Public Meeting Transcript, No. 7 at p. 150)

---

[7] Wiegman, Herman, "Final Report for the Variable Speed Integrated Intelligent HVAC Blower" (2003) (Available at: http://www.osti.gov/bridge/servlets/purl/835010-GyvYDi/native/835010.pdf).

Interested parties also commented on a constant-torque variation of the ECM motor technology (Regal Beloit's X13 motor). ACEEE commented that many alternative ECMs have been developed for original equipment manufacturer (OEM) and/or retrofit markets that need to be considered because of the fact that they are less expensive than ECMs and more efficient than PSC motors. (ACEEE, No. 19 at p. 6) ACEEE expressed concern about how to determine the incremental increase in efficiency with motors of the same type. (ACEEE, No. 19 at pp. 5-6) Rheem mentioned the X13 ECM for consideration as a technology option. Rheem described the X13 as a brushless direct current (DC) motor, with speed taps like a PSC motor. (Rheem, Public Meeting Transcript, No. 7 at p. 151) Mortex stated that the decrease in the cost gap between ECM and PSC motors could be the result of "dumbed-down" lower-end ECM models, such as the X13, which have less complex controls and fixed speed taps. Mortex noted that some of the higher-end ECMs, like the GE version 5, may still be much more costly, because of complicated controls and special impellers. (Mortex, Public Meeting Transcript, No. 7 at p. 147) Ingersoll Rand agreed with Mortex that there are less-expensive, less-complicated ECM models available that could potentially replace PSC motors. (Ingersoll Rand, Public Meeting Transcript, No. 7 at p. 147)

Interested parties compared PSC motors to ECMs. Rheem stated that the driving factor in furnace fan efficiency is the type of motor used: either PSC or ECM. According to Rheem the other details add complexity but marginal value. (Rheem, Public Meeting Transcript, No. 7 at pp. 88-89) Rheem commented that ECM motors have the ability to nearly maintain the selected airflow regardless of the ESP. Rheem added that the electrical energy consumption of an ECM can double as the ESP increases from 0.1 inch w.c. to 1 inch w.c. According to Rheem, a PSC motor is not able to maintain the selected airflow, and the airflow decreases and the electrical consumption can drop by 50 percent as the ESP increases from 0.1 inch w.c. to 1 inch w.c. (Rheem, No. 29 at p. 13) AHRI and Morrison stated that PSC motors are used in a majority of the applications because of their low cost and reliable operation. (AHRI, No. 20 at p. 8 and Morrison, No. 26 at p. 7) AHRI and Morrison stated that PSC motors typically have efficiencies in the 55-65 percent range, while ECMs are more expensive but have higher efficiencies in the 75-80 percent range. AHRI and Morrison added that ECMs have the possibility of an infinite number of operating points. According to these interested parties, Federal, State, and local programs have led to an increased adoption of higher-efficiency HVAC systems. (AHRI, No. 20 at p. 8; Morrison, No. 26 at p. 7) NRDC echoed AHRI and Morrison, stating that ECMs have been shown to save 26-32 percent of the annual electricity use compared to PSC motors. (NRDC, No. 28 at p. 5) Johnson Controls stated that ECM motors have an efficiency advantage at low loads or partial load conditions but do not have a significant efficiency advantage at higher/maximum load conditions. (Johnson, Public Meeting Transcript, No. 7 at pp. 145-146) Additionally, Ingersoll Rand noted that ECM motors, although more efficient than PSC motors, add approximately 4 watts to the furnace standby power. PSC motors do not have standby power. (Ingersoll Rand, No. 25 at p. 2) Ingersoll Rand stated that it has not noticed a significant decrease in the cost gap between ECM and PSC motors. Ingersoll Rand added that the difference is still a 300 to 400 percent cost increase. Ingersoll Rand attributes the cost difference to the built-in electronics and responsive magnets of the ECM. (Ingersoll Rand, Public Meeting Transcript, No. 7 at p. 146)

DOE recognizes the differences in ECM and PSC motor technologies. DOE is aware that these differences result in varying relative performance across the analyzed range of operation that DOE considers to be typical of residential applications. In the concurrent furnace fan test procedure NOPR, DOE used the comments regarding differential benefits for different operating conditions to develop a test metric that would provide a balanced indication of energy use covering a range of operating conditions. In addition, DOE accounted for the unique characteristics of each motor type in the preliminary analysis. DOE identified three PSC motor variations: the baseline PSC motor that has three or less airflow control settings; the improved PSC that has between three and five airflow-control settings; and a PSC motor with inverter controls. DOE also identified two ECM variations: the constant-torque ECM (*e.g.*, the Genteq X13) and the constant-speed ECM. DOE included these motor types in its preliminary analysis. For a more detailed discussion about these motor types and how DOE included them in its analyses, refer to chapters 3 and 5 of this TSD.

DOE recognizes that ECM motors contribute considerably more to standby power consumption than PSC motors. However, use of ECM motors is still practical because the increased standby consumption of ECM motors is significantly less than their active mode electrical energy savings.

Rheem noted that the design of the housing can impact the fan efficiency. According to Rheem, the following housing design improvements can improve fan efficiency: (1) optimizing the shape of the inlet cone; (2) minimizing the gaps between the impeller and the inlet cone; and (3) optimizing cut-off location and the manufacturing tolerances. (Rheem, No. 29 at p.14)

DOE investigated housing design modifications during its teardown analysis. DOE found that housing design modifications had very little impact on furnace fan efficiency. In addition, during manufacturer interviews, manufacturers estimated that housing improvements would have very little effect on fan efficiency. For these reasons, DOE is not including improved housing designs as a technology option.

2.4 SCREENING ANALYSIS

The purpose of the screening analysis is to evaluate the technologies identified in the technology assessment to determine which technologies to consider further and which technologies to screen out. DOE consulted with industry, technical experts, and other interested parties in developing a list of energy-saving technologies for the technology assessment. DOE then applied the screening criteria to determine which technologies were unsuitable for further consideration in this rulemaking. Chapter 4 of the TSD, the screening analysis, contains details about DOE’s screening criteria.

As presented in further detail below, the screening analysis examines whether various technologies: (1) are technologically feasible; (2) are practicable to manufacture, install, and service; (3) have an adverse impact on product utility or availability; and (4) have adverse impacts on health and safety. In consultation with interested parties, DOE reviewed the list of residential furnace fan technologies according to these criteria. In the engineering analysis, DOE further considers the efficiency-enhancement technologies that it did not eliminate in the screening analysis.

1. *Technological feasibility.* DOE screens out technologies that are not incorporated in commercially-available products or working prototypes.

2. *Practicability to manufacture, install, and service.* If DOE determines that mass production of a technology in commercial products and reliable installation and servicing of the technology could not be achieved on the scale necessary to serve the relevant market by the time of the compliance date of the standard, it will not consider that technology further.

3. *Adverse impacts on product or equipment utility or availability.* If DOE determines a technology has a significant adverse impact on the utility of the product for significant consumer subgroups or results in the unavailability of any covered product type with performance characteristics (including reliability), features, size, capacities, and volumes that are substantially the same as products generally available in the United States at the time, it will not consider that technology further.

4. *Adverse impacts on health or safety.* If DOE determines that a technology will have significant adverse impacts on health or safety, it will not consider that technology further.

DOE eliminated the following technology options for residential furnace fans from further consideration based on these four criteria: housing design modifications; airflow path design improvements; and ECM control relays. Chapter 4 includes a detailed discussion regarding these screened out technology options. In addition, DOE sought comment from interested parties on how the four screening criteria might apply to any additional technology option(s) that an interested party recommends to DOE.

DOE received feedback during its preliminary manufacturer impact analysis that backward-curved impellers are more sensitive to installation configurations (*i.e.*, upflow, downflow, and horizontal) than the forward-curved impellers that are currently widely used in furnace fan assemblies. Therefore, use of backward-curved impellers could impact product availability by limiting which models can be installed in certain configurations.

DOE agrees with this feedback based on its findings in related research reports (see chapter 3 of this TSD). However, DOE expects that design changes can be made to prevent impacts on product availability associated with use of backward-curve impellers. DOE is including backward-curved impellers as a design option as a result. DOE requests comment on the use of backward-curved impellers and their impact on cost, efficiency, and product availability in the Executive Summary of this TSD.

2.5 ENGINEERING ANALYSIS

The engineering analysis (chapter 5 of the TSD) establishes the relationship between manufacturing production cost and efficiency for each residential furnace fan. This relationship serves as the basis for cost-benefit calculations in terms of individual consumers, manufacturers, and the Nation. Chapter 5 discusses the product classes analyzed, representative baseline units, incremental efficiency levels, methodology used to develop manufacturing production costs, cost-efficiency curves, impact of efficiency improvements on the considered products, and methodology used to extend the analysis to low-shipment-volume product classes. To determine the cost to consumers of furnace fans at various efficiency levels, DOE estimated manufacturing costs, markups in the distribution chain, installation costs, and maintenance costs. Efficiency levels for products included in this rulemaking were calculated according to the proposed DOE test procedure.

In the engineering analysis pertaining to residential furnace fans, DOE evaluated a range of product efficiency levels and associated manufacturing costs. The purpose of the analysis is to estimate the incremental increase to selling prices that would result from increasing efficiency levels above the baseline model in each product class. The engineering analysis considers technologies not eliminated in the screening analysis. The LCC analysis uses the cost-efficiency relationships developed in the engineering analysis. In the Framework Document, DOE presented plans for its engineering analysis and sought comment on its approach to calculating the cost-efficiency relationship for furnace fans, as well as on the selection of commercially-available furnace fans with incrementally increasing efficiency from the baseline model to max-tech for characterizing the efficiencies of furnace fans currently offered for sale. DOE also sought comment on how furnace fan efficiency varies with airflow capacity, motor type, motor rated horsepower, number of speed control settings, or any other furnace parameter. DOE sought information on proprietary designs for the furnace fans under consideration in this rulemaking and, if such proprietary designs exist, how DOE can acquire the cost data necessary for evaluating these designs.

In the Framework Document, DOE sought comment on any proprietary designs of which it should be aware. As explained in the Framework Document, DOE will consider a proprietary design in subsequent analyses only if the technology does not represent a unique path to a given efficiency level. If the proprietary design is the only approach available to achieve a given efficiency level, then DOE will eliminate the efficiency level from further analysis. DOE will reject a standard level that can only be met with a single proprietary technology, because it could result in an anticompetitive market, which would be economically unjustifiable. This principle has been consistently applied in past DOE rulemakings. However, if a given energy efficiency level can be achieved by a number of design approaches, including a proprietary design, DOE will continue to examine that efficiency level, in spite of the proprietary nature of that one design.

Ingersoll Rand stated that it has a patented housing design. (Ingersoll Rand, Public Meeting Transcript, No. 7 at p. 172) However, for the reasons stated in section 2.3.4, DOE did not consider housing design improvements as a technology option, because such designs are expected to have very little impact on energy efficiency. Thus, Ingersoll Rand's proprietary housing does not represent a unique path to a given efficiency level.

Interested parties commented on the impacts of proprietary motor technologies. Nordyne explained that barriers to entry for motor manufacturers, such as aggressive intellectual property strategies, have slowed the formation of a cost-competitive market around brushless DC motor technology. (Nordyne, No. 31 at p. 3) Rheem stated that, if the energy efficiency standard was set such that PSC motors did not meet the standard, there might be shortages from the single supplier of ECMs. Also, Rheem estimates that this decrease in supply and increase in demand could drive up prices for consumers. (Rheem, No. 29 at p. 16) Rheem stated that Regal-Beloit produces the majority of their brushless permanent magnet motors and that Rheem uses Regal-Beloit's software to control their motors. Even though less-expensive brushless DC motors are available, Rheem would have to develop their controls, which prevents Rheem from purchasing from vendors other than Regal-Beloit. (Rheem, Public Meeting Transcript, No. 7 at pp. 170-171)

From comments received on the Framework Document and during interviews with furnace fan manufacturers, DOE is aware that many manufacturers rely on a single supplier of ECMs, Regal Beloit, to produce higher-efficiency furnace fans. DOE recognizes that Regal Beloit possesses a number of patents in the brushless direct-current motor space. However, DOE is aware that other motor manufacturers, such as Broad Ocean, also offer brushless DC models. DOE also expects that furnace fan manufacturers have the ability to use alternative designs, such as ECMs with controls designed in-house, as Rheem stated, to achieve the identified efficiency levels without using Regal Beloit's patented technology. DOE expects that competition from other motor manufacturers and furnace fan manufacturers developing ECM controls in-house will mitigate increases in price and possibly even drive them down. DOE included ECMs as technology options in the preliminary analysis. DOE will evaluate the potential for shortages and price increases of ECMs under standards in its NOPR analyses.

2.5.1 Baseline Models

In order to analyze technology options for energy efficiency improvements, DOE defined a baseline model unit for each furnace fan product class. The baseline model should represent the characteristics of furnace fans used in common residential HVAC products sold in a given product class. Typically, the baseline model would be a model that just meets current energy conservation standards. However, energy conservation standards for furnace fans do not exist. As a result, DOE will select baseline models typical of the furnace fans used in the least-efficient residential HVAC models offered for sale in the market. In the present case, selection of the baseline model for each product class will encompass consideration of furnace fan features and performance characteristics such as number of fan motor airflow-control settings, impeller type, and fan motor efficiency. DOE sought comment on the selection, appropriate features, and performance characteristics of baseline models for each product class.

Some interested parties commented on the teardown analysis and baseline models. Rheem commented that a baseline furnace fan has a sheet metal housing, a forward-curved impeller, a PSC or ECM motor, and an electronic control. (Rheem, No. 29 at p. 13) Rheem also commented that packaged units that use belt-driven motors are less efficient than packaged units using direct-drive motors and are not representative of the market as a baseline. (Rheem, Public Meeting Transcript, No. 7 at pp. 164-165) Mortex stated that for the manufactured home market, entry-level furnaces might have a shaded pole motor for heating that gets replaced by a kit that uses a PSC motor for heavy air-conditioning. (Mortex, Public Meeting Transcript, No. 7 at pp. 166-167)

After review of publically-available product literature, teardowns, and discussions with manufacturers, DOE found that the baseline furnace fan across all product classes includes: a direct-drive PSC motor with 3 or less airflow-control settings, a centrifugal forward-curved impeller, and a standard housing design, most often made of sheet-metal. DOE found very few commercially-available belt-driven packaged units or manufactured home units that used a shaded pole motor. Therefore, these components were not used to describe the baseline unit for these product classes.

2.5.2 Manufacturing Cost Analysis

There are several ways to develop the relationship between cost and performance. DOE chose to use a component-based engineering analysis, or teardown analysis. This approach identifies potential technological paths manufacturers could use to achieve increased product energy efficiency. DOE purchased "off-the-shelf" units commercially available on the market and dismantled them component by component to determine what technologies and designs manufacturers currently employ to increase furnace fan energy efficiency. DOE then used independent costing methods, along with manufacturer and component-supplier data, to estimate the costs of the components.

DOE determined the efficiency levels corresponding to various design options from commercially-available information on products, data submitted by manufacturers, and engineering calculations. DOE obtained cost estimates from detailed incremental manufacturing cost data based on reverse engineering, which include the cost of the product components, labor, purchased parts and materials, and investment. DOE estimated manufacturing costs using a combination of teardown analysis and manufacturer-supplied estimates.

2.6 MARKUPS ANALYSIS

DOE uses manufacturer-to-customer markups to convert the manufacturer selling price estimates from the engineering analysis to customer prices, which are then used in the LCC and PBP analysis and in the manufacturer impact analysis. Retail prices are necessary for the baseline efficiency level and all other efficiency levels under consideration. DOE estimates these retail prices by applying manufacturer-to-customer markups to the manufacturer selling price calculated as part of the engineering analysis.

Before developing markups, DOE defines key market participants and identifies distribution channels. Generally, the furnace distribution chain includes six market participants: (1) distributors; (2) dealers; (3) general contractors; (4) mechanical contractors; (5) installers; and (6) builders. For the markups analysis, DOE combined mechanical contractors, dealers, and installers in a single category labeled "mechanical contractors," because these terms are used interchangeably by the industry. Because builders serve the same function in the HVAC market as general contractors, DOE included builders in the "general contractors" category.

Rheem stated that the furnace fan is a component in a furnace, so the distribution path would be the same as a furnace. (Rheem, No. 29 at p. 15) Adjuvant supported DOE's analysis of markups, except that the commenter suggested that manufactured housing should be considered a separate distribution channel. (Adjuvant, No. 9 at p. 7)

DOE is using the same distribution channels for furnace fans as it used for furnaces in a recent energy conservation standards rulemaking for those products. 76 FR 37408 (June 27, 2011)[8] DOE believes that this is an appropriate approach, because the vast majority of the furnace fans covered in this rulemaking are a component of a furnace. DOE also believes that the furnace fans covered in this rulemaking that are a component in a non-furnace HVAC product will have similar distribution channels. Manufactured housing furnace fans have a separate distribution channel.

Several parties commented on the market and distribution channel for replacement fans. Adjuvant stated that the replacement fan market will be very small. (Adjuvant, No. 9 at p. 7) Johnson Controls stated that certain furnace fan manufacturers provide products for field replacement that are considered to be "universal" replacements for the original equipment manufacturer's products; these may include upgrades for motors, and these field replacements use a similar distribution path as original products. (Johnson, No. 15 at p. 12) Johnson Controls further stated that in the manufactured housing market, the add-on application of air conditioning may require a larger, different furnace fan assembly as a field replacement for the heating-only furnace fan already installed in the manufactured home. (Johnson, No. 15 at p. 12)

DOE understands that the market for replacement fans is very small, and it has not included this distribution channel in the preliminary analysis. DOE requests comment regarding whether this channel is large enough to merit inclusion, and, if so, what would be an appropriate assumption for its market share.

Regarding estimation of markups for furnace fans, Rheem stated that, because a furnace fan is a component in a furnace, the overall markups would be the same as for a furnace. (Rheem, No. 29 at p. 15) Ingersoll Rand stated that once in the furnace manufacturer's plant, the blower and motor essentially lose their identity as far as margins and markups; they are simply part of the furnace and are not priced separately. (Ingersoll Rand, No. 25 at p. 4)

DOE generally agrees with the comments made by Rheem and Ingersoll Rand and has estimated markups for furnace fans using the same approach as it used for furnaces in the recent rulemaking for that product. DOE expects this approach to be appropriate because the majority of the furnace fans covered in this rulemaking are components of a furnace. DOE also expects that the markups for furnace fans used in HVAC products other than furnaces that are covered in this rulemaking will have similar markups.

DOE develops baseline and incremental markups to transform the manufacturer selling price into a consumer product price. DOE uses the baseline markups, which cover all of a

---

[8] http://www1.eere.energy.gov/buildings/appliance_standards/residential/residential_furnaces_central_ac_hp_direct_final_rule_tsd.html

distributor's or contractor's costs, to determine the sales price of baseline models. Incremental markups are coefficients that DOE applies to the incremental cost of higher-efficiency models.

ACEEE stated that the markups associated with ECMs are greater than the markups of other variable-speed motors with similar outputs, but that DOE's analysis for standards considerations should be based on costs in a commodity market, in which ECMs are produced in large quantity. (ACEEE, No. 19 at p. 6) In response, DOE assumes that the markups on products at each considered efficiency level reflect the large production volume and resulting costs that would occur in the case of standards at that level.

Johnson Controls stated that products for field replacement have markups that can be much different than those on the original product. (Johnson, No. 15 at p. 12) As previously stated, DOE understands that the market for replacement fans is a very small share, and it has not included this distribution channel in the preliminary analysis.

2.7 ENERGY USE ANALYSIS

The purpose of the energy use analysis is to determine the annual energy consumption of furnace fans in representative U.S. homes and to assess the energy savings potential of increased fan efficiency. DOE estimated the annual energy consumption of furnace fans at specified energy efficiency levels across a range of climate zones. The annual energy consumption includes the electricity use by the fan, as well as the change in natural gas, liquid petroleum gas (LPG), electricity, or oil use for heat production as result of the change in the amount of useful heat provided to the conditioned space as a result of the furnace fan. The annual energy consumption of furnace fans is used in subsequent analyses, including the LCC and PBP analysis and the national impact analysis.

Lennox stated that the current DOE test procedures for determining furnace fan energy consumption (*i.e.*, the test procedures for HVAC equipment) have evolved through the cooperative efforts of DOE and industry over the past 25 years. Lennox stated that these test procedures contain: uniform provisions for the measurement of furnace fan energy consumption in heating and cooling operation; methods to test and rate single-stage, multi-stage, and modulating furnaces and air-conditioning systems; statistical methods of establishing ratings based on defined confidence levels; and a method to estimate annual furnace fan energy consumption for each furnace and air conditioner model tested and rated. (Lennox, No. 23 at pp. 1-2)

DOE used the existing DOE test procedures for furnaces and air conditioners to estimate heating and cooling mode operating hours for the furnace fan. The power consumption of the furnace fan is determined using the individual sample housing unit operating conditions (the pressure and airflow) at which a particular furnace fan will operate when performing heating, cooling, and continuous circulation functions. The methodology and the data are fully described in chapter 7 of this TSD.

Lennox stated that any reduction in the electrical energy in the blower is offset by an increase in primary fuel consumption. (Lennox, No. 23 at p. 3) DOE's analysis accounts for changes in the furnace fan heat contribution, which affects the house heating and cooling load.

Morrison stated that energy consumption by fans varies greatly depending on product design, climate, usage patterns, and installation. (Morrison, No. 26 at p. 7) DOE's analysis accounts for the variety of furnace fan designs and field conditions.

In the Framework Document, DOE stated that it planned to use the Energy Information Administration's (EIA) Residential Energy Consumption Survey (RECS)[9] to establish a sample of households using furnace fans for each furnace fan product class. RECS data provide information on the age of furnaces with furnace fans, as well as heating and cooling energy use in each household. The survey also includes household characteristics such as the physical characteristics of housing units, household demographics, information about other heating and cooling products, fuels used, energy consumption and expenditures, and other relevant data. DOE uses the household samples not only to determine furnace fan annual energy consumption, but also as the basis for conducting the LCC and PBP analysis.

Johnson Controls stated that the RECS 2005 data would require some modification in light of the changes to the housing market and the HVAC market since that time. It noted that add-on or replacement HVAC markets have been significantly altered by the availability and scope of Federal tax credits, weatherization programs, utility rebates, and manufacturer rebates to home owners. (Johnson, No. 15 at p. 13) Lennox made similar comments to those made by Johnson Controls regarding the use of RECS 2005 data and stated that RECS 2009 should be used. (Lennox, Public Meeting Transcript, No. 7 at pp. 190-191)

In response, DOE notes that RECS 2009 furnace heating and cooling energy use data were not available for the preliminary analysis. DOE is using RECS 2005 heating and cooling energy use data to determine heating and cooling operating hours. RECS data do not provide any information about the furnace fan, so using RECS 2009 would not capture furnace fan market trends. DOE used data from RECS 2009,[10] American Housing Survey (AHS) 2009,[11] and the Census Bureau[12] to project household weights and household characteristics in 2018, which is the compliance date of any new energy efficiency standard for furnace fans. These adjustments account for housing market changes since 2005, as well as for projected product and demographic changes.

The power consumption (and overall efficiency) of a furnace fan depends on the speed at which the motor operates, the external static pressure difference across the fan, and the airflow through the fan. To calculate furnace fan electricity consumption, DOE determined the operating

---

[9] Energy Information Administration, 2005 Residential Energy Consumption Survey (Available at: http://www.eia.doe.gov/emeu/recs).

[10] http://www.eia.gov/consumption/residential/data/2009/

[11] http://www.census.gov/housing/ahs/data/national.html

[12] http://www.census.gov/popest/

conditions (the pressure and airflow) at which a particular furnace fan will operate in each RECS housing unit when performing heating, cooling, and continuous-circulation functions.

The Consortium for Energy Efficiency (CEE) stated that duct pressure affects airflows and motor performance and must be considered in any energy savings calculation. CEE stated that systems are often analyzed using duct pressures of 0.2 in. wc, but in practice only a small percentage of systems operate in that range, even during the heating season. CEE stated that the external static pressure measured in 81 homes in heating mode averaged 0.55 in. wc. (CEE, No. 22 at p. 1) Rheem stated that DOE should assume that external static pressure is consistent with the manufacturer's installation instructions. (Rheem, No. 29 at p. 15)

DOE gathered field data from available studies and research reports to determine an appropriate distribution of ESP values. DOE compiled over 1,300 field ESP measurements from several studies that included furnace fans in single-family and manufactured homes in different regions of the country. The average ESP value in the cooling operating mode from these studies results in an average 0.65 in. wc for single-family households and 0.30 in. wc for manufactured homes. The full methodology and the data are described in chapter 7 of this TSD.

Johnson Controls stated that determining the required furnace fan operating hours in heating mode is included in the blower energy (BE) factor already used as part of the AFUE calculation process, so estimating furnace fan electrical energy use can be done with some modifications. (Johnson, No. 15 at p. 13) DOE determined furnace fan operating hours in heating mode by calculating the furnace burner operating hours and adjusting them for delay times between burner and fan operation. Burner operating hours are a function of annual house heating load, furnace efficiency, and furnace input capacity.

Adjuvant stated that the number of hours per year used for low-speed air circulation is the biggest unknown in the energy use analysis and urged DOE to acquire some field data for this variable. (Adjuvant, No. 9 at p. 7) CEE stated that out of 70 homeowners surveyed in a study it sponsored, 70 percent of respondents never used the "Fan On" mode and always used the fan in "Auto" mode with the fan only running for heating or cooling; 13 percent of respondents used the "Fan On" setting all the time; and 17 percent of respondents alternated between the two settings. (CEE, No. 22 at pp. 1-2) Johnson Controls stated that determining continuous circulation hours as equal to all of the remaining hours after heating and cooling operation is not justifiable. Johnson Controls stated that while many homes use the continuous furnace fan option, there are not sufficient data to establish that this operating condition is a default mode. It added that home thermostats do not always include this operational mode, and there are vast differences in the actual operating modes available for continuous fan or ventilation options. (Johnson, No. 15 at p. 13)

DOE did not assume that continuous circulation hours are equal to all of the remaining hours after heating and cooling operation. To estimate use of continuous circulation in the sample homes, DOE evaluated the available studies, which include a recent survey in

Minnesota,[13] a 2009 program evaluation report from Wisconsin,[14] and 2003 Wisconsin field monitoring of residential furnaces.[15] DOE did not use these data directly, however, because it believes they are not representative of consumer practices for the U.S. as a whole. In these States, many homes have low air infiltration and there is a high awareness of indoor air quality issues, which could lead to significant use of continuous circulation. To develop U.S. average values, DOE modified the data from the upper Midwest using information from manufacturer product literature and consideration of climate conditions in other regions. The continuous circulation hours that DOE used are described in chapter 7 of this TSD. DOE requests comments on its characterization of use of continuous circulation, and information that would support use of alternative assumptions.

Morrison stated that the analysis accounts for heating and cooling hours, and the remaining hours are assigned to ventilation, leaving no time for standby power. (Morrison, Public Meeting Transcript, No. 7 at pp. 191-192) DOE estimated the number of hours in standby mode for the sample households that use continuous circulation some of the time and for those that never use continuous circulation.

Ingersoll Rand stated that the electrical energy used [by the fan] for cooling operation or heat pump heating operation should not be part of this rule, as that energy is already part of the SEER and HSPF ratings for air conditioners and heat pumps. (Ingersoll Rand, No. 25 at p. 1) Johnson Controls stated that furnace fan operating hours for air-conditioning applications are included in the SEER calculation, and the same consideration is found in the SEER and HSPF for heat pump applications. Johnson Controls stated that estimating such furnace fan energy use in this rulemaking is redundant and overstates electrical usage. (Johnson, No. 15 at p. 13) Adjuvant urged DOE to avoid double-counting savings from already covered air-conditioning products. (Adjuvant, No. 9 at p. 11)

As previously discussed, DOE recognizes that the energy savings in cooling mode from higher-efficiency furnace fans used in some higher-efficiency CAC and heat pumps was already accounted for in the analysis of standards on those products. To avoid double-counting, the analysis for furnace fans does not include furnace fan electricity savings that were counted in DOE's analysis for CAC and heat pump products. That analysis considered savings from households with a CAC or heat pump at SEER 15 or above who would already have an ECM fan. Correspondingly, the base case efficiency distribution of fans used in the present analysis considers the presence of those ECM fans in future CAC or heat pump shipments. Since the energy savings from the considered fan efficiency levels are measured relative to the base case efficiencies, any savings reported here are over and above those counted in the CAC and heat pump rulemaking.

---

[13] Provided in CEE, No. 22 at pp. 1-2.
[14] State of Wisconsin, Public Service Commission of Wisconsin, Focus on Energy Evaluation Semiannual Report, Final (April 8, 2009).
[15] Pigg, S. 2003, Electricity Use by New Furnaces: A Wisconsin Field Study (October 2003) (Available at http://www.doa.state.wi.us/docview.asp?docid=1812).

Several parties commented on the possibility of consumers using higher-efficiency furnace fans more than baseline furnace fans. Such change in behavior when operating costs decline is known as a rebound effect. Rheem stated that a rebound effect should be considered for furnace fans. It cited an evaluation report from Wisconsin[16] that indicates that a considerable number of homeowners who purchase ECM furnaces significantly increase the frequency with which they operate their furnace fan subsequent to the installation of the ECM furnace, thereby negating some or all of the energy savings from the fan. (Rheem, No. 29 at pp. 15-16) ACEEE stated that the rebound effect is likely to be small. It noted that some consumers may adopt full-time circulation when they buy advanced air handlers, but estimating this kind of "rebound" is problematic because of the large uncertainties about the fraction of purchasers who would consider this mode but do not use it currently. (ACEEE, No. 19 at p. 6) AHRI stated that the idea of a rebound effect for a furnace fan does not hold, as consumers would not react if their blower is more efficient. (AHRI, Public Meeting Transcript, No. 7 at pp. 193-194) Morrison stated that it is not clear what percentage of consumers use the continuous ventilation mode, so an assumption might need to be made about a rebound effect. (Morrison, No. 26 at p. 8)

After reviewing the available information, DOE concluded that inclusion of a rebound effect in its analysis is warranted. DOE used the aforementioned report from Wisconsin to estimate the extent to which increased use of continuous circulation under a standard requiring ECM furnace fans is likely to cancel out some of the savings from such a fan. The specific assumptions are described in chapter 7 of this TSD. DOE requests comments on the reasonableness of the values that it used to characterize this rebound effect.

2.8 LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

In determining whether an energy efficiency standard is economically justified, DOE considers the economic impact of potential standards on customers. The effect of new or amended standards on individual customers usually includes a reduction in operating cost and an increase in purchase cost. DOE uses the following two metrics to measure consumer impacts:

- LCC (life-cycle cost) is the total customer cost of an appliance or product, generally over the life of the appliance or product, including purchase and operating costs. The latter consist of maintenance, repair, and energy costs. Future operating costs are discounted to the time of purchase and summed over the lifetime of the appliance or product.
- PBP (payback period) measures the amount of time it takes customers to recover the assumed higher purchase price of a more energy-efficient product through reduced operating costs.

DOE analyzed the net effect of potential furnace fan standards on consumers by calculating the LCC and PBP using the engineering performance data, the energy-use data, and the markups. Inputs to the LCC calculation include the installed cost to the consumer (purchase

---

[16] State of Wisconsin, *op. cit*.

price plus installation cost), operating expenses (energy expenses, and, if applicable, repair costs and maintenance costs), the lifetime of the product or other defined period of analysis, and a discount rate. Inputs to the payback period calculation include the installed cost to the consumer and first-year operating costs.

DOE performed the LCC and PBP analyses using a spreadsheet model combined with Crystal Ball (a commercially-available software program used to conduct stochastic analysis using Monte Carlo simulation and probability distributions) to account for uncertainty and variability among the input variables. Each Monte Carlo simulation consists of 10,000 LCC and PBP calculations. The model performs each calculation using input values that are either sampled from probability distributions and household samples or characterized with single point values. The analytical results include a distribution of 10,000 data points showing the range of LCC savings and PBPs for a given efficiency level relative to the base-case efficiency forecast.

Adjuvant stated that the furnace fan lifetime is essentially the life of the furnace. (Adjuvant, No. 9 at p. 8) Johnson Controls stated that furnace fan lifetimes are considered to the equivalent to the life of the furnace, typically considered as 20 years with normal maintenance and inspections. (Johnson, No. 15 at p. 14) Ingersoll Rand stated that the service life of the motor and bearings is on the same order as that of the furnace; the service life of the electronics for an ECM should be expected to be lower, but is not yet fully characterized. (Ingersoll Rand, No. 25 at p. 4) Rheem stated that the actual lifetime of a furnace fan is generally dependent on the life of the motor, which is dependent on bearing life, which in turn is dependent on the number of on/off cycles and bearing temperature. (Rheem, No. 29 at p. 16)

DOE modeled furnace fan lifetime based on the distribution of furnace lifetimes developed for the recent furnace rulemaking.[17] DOE assumed that the lifetime is the same for fans at different efficiency levels. DOE modeled fan motor failure and replacement as a repair cost that affects a certain percentage of fans, as discussed below.

Ingersoll Rand stated that the blower wheel should never need to be serviced, nor should the motor or bearings. (Ingersoll Rand, No. 25 at p. 4) Johnson Controls stated that maintenance costs are the same for various furnace fan products. (Johnson, No. 15 at p. 14) Adjuvant stated that maintenance costs for more-efficient furnace fans are highly unlikely to be different than for less-efficient models. (Adjuvant, No. 9 at pp. 7-8) DOE agrees with the comments and assumed that maintenance costs are the same for furnace fans at different efficiency levels.

Johnson Controls stated that repair costs for furnace fans are basically the cost of replacing the motor, as there are very few failures of the components other than the motor; as most residential HVAC products are covered by 10-year parts warranties, there are no repair costs during that time frame. Adjuvant recommended that DOE attempt to acquire data on the size of the fan motor replacement market and the average cost of replacements for each motor type. (Adjuvant, No. 9 at pp. 7-8) Ingersoll Rand stated that the introduction of electronic drives

[17] http://www1.eere.energy.gov/buildings/appliance_standards/residential/residential_furnaces_central_ac_hp_direct_final_rule_tsd.html

has led to new failure modes for certain fan motors, but public data on such failures are extremely limited. (Ingersoll Rand, No. 25 at p. 4) Johnson Controls stated that the life of ECMs may be considered the same [as PSC motors] except in those geographical areas where large variations in the electrical power grid can occur, or the weather patterns provide increased exposure to lightning strikes. (Johnson, No. 15 at p. 14)

DOE included motor replacement as a repair cost for a fraction of furnace fans. To estimate rates of fan failure, DOE developed a distribution of fan motor lifetime (expressed in operating hours) by motor size using data from DOE's rulemaking for small electric motors.[18] DOE then paired these data with the calculated number of annual operating hours for each sample furnace. Motor costs were based on costs developed in the engineering analysis. The labor time and costs were based on RS Means data.[19,20]

Johnson Controls stated that, outside the warranty period, the replacement costs for ECMs can be three to five times the replacement cost of PSC motors due to greater complexity and the electronic controls required to use them. (Johnson, Public Meeting Transcript, No. 7 at p. 203) Adjuvant stated that in the case of motor replacement, permanent magnet DC motors are more expensive than the PSC motors that would be replaced. (Adjuvant, No. 9 at pp. 7-8)

DOE had no information indicating the extent to which consumers would replace a fan PSC motor with an ECM, so it assumed that when replacement is necessary, consumers replace the failed motor with the same type of motor.

Rheem stated that the discount rate for furnace fans would be the same as it is for furnaces. (Rheem, No. 29 at p. 16) DOE used the same discount rates for furnace fans as it used in the recent rulemaking for furnaces.

To estimate the share of consumers that would be affected by an energy conservation standard at a particular efficiency level, DOE's LCC and PBP analysis considers the projected distribution (*i.e.*, market shares) of product efficiencies in the compliance year under the base case (*i.e.*, the case without new or amended energy conservation standards).

Adjuvant stated that there is a strong trend toward more-efficient air handlers, much of it driven by incentives and programs such as ENERGY STAR, but the trends are more obvious in some parts of the country than in others. (Adjuvant, No. 9 at p. 9) Morrison stated that the adoption rate of higher-efficiency products has increased in recent years as higher-efficiency HVAC systems receive incentives from local, State, and Federal government and utility programs. (Morrison, No. 26 at p. 8) ACEEE stated that the efficiency distribution absent efficiency standards is uncertain and should not be speculated upon by DOE. (ACEEE, No. 19 at p. 6)

[18] http://www1.eere.energy.gov/buildings/appliance_standards/commercial/sem_finalrule_tsd.html
[19] RS Means Company Inc., *RS Means Residential Cost Data* (2011).
[20] RS Means Company Inc., *Facilities Maintenance & Repair Cost Data* (2011).

DOE agrees that market trends in HVAC system efficiency influence the market shares of different furnace fan efficiency levels. However, DOE found very limited historical data upon which to estimate either current shares or recent trends. To start, DOE used Rheem's comment, stating that the market share for ECM motors has increased from 10 percent to 30 percent within the last five years. (Rheem, No. 29 at p. 3) To estimate the market share for ECM motors in 2018, DOE developed data on the share of models in each product class with an ECM design.[21] The resulting estimate for 2018 is a 45-percent share for ECM fans out of the overall market for furnace fans. The market shares of each ECM fan efficiency level are derived from the data on number of models. No such data were available for the PSC fan efficiency levels, so DOE assumed that half of shipments are at the baseline level and half are "improved PSC" fans. There are currently no models of PSC with a controls design, so DOE assumed zero market share for such units. The details of DOE's approach are described in chapter 8 of this TSD. DOE requests comments on its estimate of the base-case efficiency distribution of furnace fans in 2018, as well as data that might support use of different assumptions.

2.9 SHIPMENTS ANALYSIS

DOE uses forecasts of product shipments to calculate the national impacts of standards on energy use, NPV, and future manufacturer cash flows. DOE develops shipment forecasts based on an analysis of key market drivers for each product.

The vast majority of furnace fans are shipped installed in furnaces, so DOE estimated furnace fan shipments by projecting furnace shipments in three market segments: (1) replacements; (2) new housing; and (3) new owners in buildings that did not previously have a gas furnace.

To forecast furnace replacement shipments, DOE developed retirement functions for furnaces from the lifetime estimates and applied them to the existing products in the housing stock. The existing stock of products is tracked by vintage and developed from historical shipments data.

Adjuvant stated that DOE should not use estimates of furnace fan lifetime to estimate shipments, as this leads to shipments estimates that are significantly different than manufacturer data. (Adjuvant, No. 9 at p. 9) DOE's shipments analysis uses a distribution of furnace lifetimes to estimate furnace replacement shipments.

To forecast shipments to the new housing market, DOE utilized forecasted new housing construction and historic saturation rates of various furnace and cooling product types in new housing. DOE used *AEO 2011* for forecasts of new housing. Furnace saturation rates in new housing are provided by the U.S. Census Bureau's *Characteristics of New Housing*.[22]

---

[21] DOE used the AHRI Directory of Certified Furnace Equipment (Available at: http://www.ahridirectory.org/ahridirectory/pages/home.aspx) as well as manufacturer product literature.
[22] Available at: http://www.census.gov/const/www/charindex.html.

Johnson Controls stated that there is a market for replacement fans due to add-on application of air conditioning in manufactured housing and that these shipments might be estimated using information from a source such as the Manufactured Housing Institute. (Johnson, No. 15 at p. 15) DOE did not include this market segment, because it was not able to find data that would allow estimation of shipments.

In the Framework Document, DOE stated it would consider the market segment consisting of homes built without central heating in which a furnace is later installed. Adjuvant stated that conversions from non-ducted systems to ducted systems will be very rare, because installing a duct system in an existing home that does not yet have one can be daunting and expensive. (Adjuvant, No. 9 at p. 8) DOE agrees that the magnitude of conversions from non-ducted systems to ducted systems is likely to be very small. However, DOE did include a market segment consisting of households that have central air conditioning alone or central air conditioning and electric heating and choose to install a gas furnace.

DOE considered whether standards that require more-efficient furnace fans would have an impact on furnace shipments. Ingersoll Rand stated that an increase in repair (instead of replacement) is likely to occur as a result of higher efficiency standards, as well as a decrease in sales. (Ingersoll Rand, Public Meeting Transcript, No. 7 at p. 224) Johnson Controls stated that standards would impact the manufactured housing market for add-on cooling applications and might impact the shipment of furnace fans for certain applications. (Johnson, No. 15 at p. 15) Adjuvant stated that given the success of much more efficient (and expensive) furnace fan systems in many markets today, it is unlikely that a standard requiring high-efficiency furnace fans would have an adverse effect on shipments. (Adjuvant, No. 9 at p. 9)

DOE believes that, consistent with economic theory and its past practice, it is reasonable to expect that standards that result in higher furnace prices will have some dampening effect on sales. Some consumers might choose to repair their existing furnace rather than purchase a new one. To estimate the impact of the price increase for the considered efficiency levels, DOE used the relative price elasticity approach that was applied in the 2011 furnace standards rulemaking.[23] This approach gives some weight to the operating cost savings from higher-efficiency products. The impact of higher furnace prices (due to more-efficient fans) is expressed as a percentage drop in market share for each year during the analysis period.

2.10 NATIONAL IMPACT ANALYSIS

The NIA assesses the NES and the NPV from a national perspective of total consumer costs and savings expected to result from new or amended energy conservation standards at specific efficiency levels. DOE determined the NPV and NES for the standard levels considered for the furnace fan product classes analyzed. To make the analysis more accessible and transparent to all interested parties, DOE prepared a Microsoft Excel spreadsheet that uses

[23] http://www1.eere.energy.gov/buildings/appliance_standards/residential/residential_furnaces_central_ac_hp_direct_final_rule_tsd.html

typical values (as opposed to probability distributions) as inputs. To assess the effect of input uncertainty on NES and NPV results, DOE has developed its spreadsheet model to conduct sensitivity analyses by running scenarios on specific input variables.

Analyzing impacts of potential energy conservation standards for residential furnace fans requires comparing projections of U.S. energy consumption with new or amended energy conservation standards against projections of energy consumption without the standards. The forecasts include projections of annual appliance shipments, the annual energy consumption of new appliances, and the purchase price of new appliances.

A key component of DOE's NIA analysis is the energy efficiencies forecasted over time for the base case (without new standards) and each of the standards cases. The forecasted efficiencies represent the annual shipment-weighted energy efficiency of the products under consideration during the forecast period (*i.e.*, from the assumed compliance date of a new standard to 30 years after compliance is required).

Johnson Controls stated that residential tax credits, weatherization programs, utility rebates, and manufacturer-to-consumer rebates drive the consumer toward purchasing high-efficiency HVAC products that require high-efficiency furnace fans, so changes in those incentives will drive furnace fan efficiency levels. (Johnson, No. 15 at p. 14) Johnson Controls stated that, because furnace fan efficiency is already considered in the efficiency rating for air conditioners and heat pumps, the energy efficiency standards for those products will drive the long-term change in furnace fan efficiency. (Johnson, No. 15 at p. 15)

DOE agrees that trends in HVAC product efficiency due to either future standards or other incentives are a major factor driving furnace fan efficiency. However, it is uncertain to what extent incentives will play a role after 2018 and to what degree future standards for residential HVAC products will require high-efficiency furnace fans. For this preliminary analysis, DOE derived a growth rate in the market share of ECM fans by extrapolating the trend from 2005, when the ECM share was 10 percent, to 2010, when it was approximately 30 percent. In so doing, DOE considered the favorable cost-effectiveness of ECM fans and assumed that their market share would peak and level off at 79 percent. DOE requests comments on the reasonableness of its approach and information that would support use of alternative assumptions.

To estimate the impact that standards may have in the year compliance is required, DOE has generally used a "roll-up" scenario, a "shift" scenario, or both in its standards rulemakings. Under the "roll-up" scenario, DOE assumes: (1) product efficiencies in the base case that do not meet the standard level under consideration would "roll-up" to meet the new standard level; and (2) product efficiencies above the standard level under consideration would not be affected. Under the "shift" scenario, DOE retains the pattern of the base-case efficiency distribution but re-orients the distribution at and above the new minimum energy conservation standard. DOE will evaluate whether one of these approaches is more reasonable for furnace fans or whether it would be preferable to use both scenarios in its calculation of national impacts.

AHRI stated that the only efficiency change that makes sense is a roll-up scenario. (AHRI, Public Meeting Transcript, No. 7 at pp. 230) Adjuvant stated that the efficiency step is fairly large for a furnace fan standard that required a permanent-magnet, variable-speed DC motor, and there would be limited additional efficiency potential; according to Adjuvant, this strongly suggests that DOE should use a "roll up" scenario for estimating the impacts of the standards in this case. (Adjuvant, No. 9 at p. 9) DOE agrees with these comments and has used a "roll up" scenario for estimating the impacts of the potential standards for furnace fans. To be consistent with the assumption regarding base-case efficiency after the compliance year, DOE assumed that for each standards case, the efficiency distribution in each product class remains unchanged after 2018.

2.10.1 National Energy Savings Analysis

The inputs for determining the national energy savings for each product analyzed are: (1) annual energy consumption per unit; (2) shipments; (3) product or equipment stock; (4) national energy consumption; and (5) site-to-source conversion factors. DOE calculated the national energy consumption by multiplying the number of units (stock) of each product (by vintage or age) by the unit energy consumption (also by vintage). Vintage represents the age of the product. DOE calculated annual NES based on the difference in national energy consumption for the base case (without new efficiency standards) and for each higher efficiency standard. DOE estimated energy consumption and savings based on site energy and converted the electricity consumption and savings to source (primary) energy using annual conversion factors derived from the most recent version of the National Energy Modeling System (NEMS). Cumulative energy savings are the sum of the NES for each year over the timeframe of the analysis.

DOE has historically presented NES in terms of primary energy savings. DOE has recently published a Statement of Policy regarding its intent to incorporate full-fuel-cycle (FFC) metrics into its analyses, and outlining a proposed approach. DOE stated that it intends to calculate FFC energy and emission impacts by applying conversion factors generated by the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model to the NEMS-based results currently used by DOE. 76 FR 51281 (Aug. 18, 2011). Additionally, DOE will review alternative approaches to estimating these factors and may decide to use a model other than GREET to estimate the FFC energy and emission impacts in any particular future appliance efficiency standards rulemaking. For this preliminary analysis, DOE calculated FFC energy savings using a NEMS-based methodology described in appendix 10-B. Chapter 10 of this TSD presents both the primary NES and the FFC energy savings for the considered candidate standard levels (CSLs).

2.10.2 Net Present Value Analysis

The inputs for determining NPV are: (1) total annual installed cost; (2) total annual savings in operating costs; (3) a discount factor to calculate the present value of costs and savings; (4) present value of costs; and (5) present value of savings. DOE calculated net savings each year as the difference between the base case and each standards case in terms of total savings in operating costs versus total increases in installed costs. DOE calculated savings over the lifetime of products shipped in the forecast period. DOE calculated NPV as the difference between the present value of operating cost savings and the present value of total installed costs.

DOE used a discount factor based on real discount rates of 3 and 7 percent to discount future costs and savings to present values.

For the NPV analysis, DOE calculates increases in total installed costs as the difference in total installed cost between the base case and standards case (*i.e.*, once the standards take effect). Because the more-efficient products bought in the standards case usually cost more than products bought in the base case, cost increases appear as negative values in the NPV.

DOE expresses savings in operating costs as decreases associated with the lower energy consumption of products bought in the standards case compared to the base efficiency case. Total savings in operating costs are the product of savings per unit and the number of units of each vintage that survive in a given year.

Adjuvant urged DOE to focus on use of the 3-percent discount rate in its analyses, because today's energy and climate environment speaks forcefully for the use of a discount rate that is a social discount rate, rather than one related to the cost of private capital. (Adjuvant, No. 9 at p. 10) DOE estimates the NPV of consumer benefits using both a 3-percent and a 7-percent real discount rate. DOE uses these discount rates in accordance with guidance provided by the Office of Management and Budget (OMB) to Federal agencies on the development of regulatory analysis. (OMB Circular A-4 (Sept. 17, 2003), section E, "Identifying and Measuring Benefits and Costs")

2.11 CONSUMER SUBGROUP ANALYSIS

At the NOPR stage of this rulemaking, DOE will conduct a LCC subgroup analysis. A consumer subgroup comprises a subset of the population that may be affected disproportionately by new or revised energy conservation standards (*e.g.*, low-income consumers, seniors). The purpose of a subgroup analysis is to determine the extent of any such disproportional impacts.

Regal Beloit stated that the homebuilder market should be considered a consumer subgroup, as this market typically utilizes the lowest-cost, least-efficient system. (Regal Beloit, No. 32 at p. 5) DOE's analysis accounts separately for new construction and replacement markets. In the LCC spreadsheet, the analytical results are reported separately for the two markets, thereby capturing the impacts of potential standards in the new construction market.

Johnson Controls stated that manufactured housing should be considered as a subgroup due to its unique requirements for product design under the HUD codes, application and market considerations, and due to the economic conditions of that home owner group. (Johnson, No. 15 at p. 16) Mortex also stated that DOE should consider manufactured housing as a subgroup. (Mortex, Public Meeting Transcript, No. 7 at pp. 233-234) Fans used in manufactured housing furnaces are a separate product class for this rulemaking, so they are analyzed separately in the LCC and PBP analysis. Therefore, no subgroup analysis is needed.

2.12 MANUFACTURER IMPACT ANALYSIS

In the NOPR phase, DOE will perform a manufacturer impact analysis (MIA) to estimate the financial impact of potential energy conservation standards on residential furnace fan manufacturers, as well as to calculate the impact of such standards on employment and manufacturing capacity. The MIA has both quantitative and qualitative aspects. The quantitative part of the MIA relies on the government regulatory impact model (GRIM), an industry-cash-flow model customized for these industries. The GRIM inputs are information on the industry cost structure, shipments, and revenues. This includes information from many of the analyses described above, such as manufacturing costs and prices from the engineering analysis and shipments forecasts. The key GRIM output is the industry net present value (INPV). Different sets of input assumptions (scenarios) will produce different results. The qualitative part of the MIA addresses factors such as product characteristics, characteristics of particular firms, and market and product trends, and it also includes assessment of the impacts of standards on manufacturer subgroups. Chapter 12 of the TSD describes the MIA in further detail.

DOE conducts each MIA in three phases. In Phase I, DOE creates an industry profile to characterize the industry and identify important issues that require consideration. DOE performed preliminary manufacturer interviews for the preliminary analysis as part of its Phase I activities. In Phase II, DOE prepares an industry cash-flow model and interview questionnaire to guide subsequent discussions. In Phase III, DOE interviews manufacturers and assesses the impacts of standards quantitatively and qualitatively. DOE assesses industry and subgroup cash flow and NPV using the GRIM. DOE then assesses impacts on competition, manufacturing capacity, employment, and regulatory burden based on manufacturer interview feedback and discussions.

Interested parties commented on the cumulative regulatory burden associated with this rulemaking. AHRI warned that with new certification and enforcement standards also being discussed, DOE requirements could potentially be so burdensome to manufacturers that the industry will be bankrupt in 20 years. (AHRI, Public Meeting Transcript, No. 7 at p. 264) Rheem provided a list of other regulations with which it will have to comply in addition to furnace fan standards that it suggests DOE should consider when evaluating cumulative regulatory burden, including: (1) California emissions requirements for furnaces; (2) other rulemakings associated with furnaces and boilers, CAC and heat pump products, water heaters, direct heating equipment, and pool heaters; (3) certification and enforcement requirements; (4) State building code requirements; (5) SCAQMD Rule 1111; and (6) CSA C823. (Rheem, Public Meeting Transcript, No. 7 at pp. 248-249; Rheem, No. 29 at p. 14; Rheem, No. 29 at p. 17) AHRI and Johnson Controls agreed with Rheem, adding EPA programs like ENERGY STAR to the list of regulatory burdens that furnace fan manufacturers face. (AHRI, Public Meeting Transcript, No. 7 at p. 248; Johnson, Public Meeting Transcript, No. 7 at pp. 249-250) Johnson Controls also added that regulations for similar commercial products, changes in refrigerant requirements, NO_x emissions requirements, weatherization programs, and utility requirements will all impact furnace fan manufacturers as well. (Johnson, Public Meeting Transcript, No. 7 at pp. 249-250)

DOE recognizes that while any one regulation may not impose a significant burden on manufacturers, the combined effects of several impending regulations may have serious consequences for some manufacturers, groups of manufacturers, or an entire industry. Assessing the impact of a single regulation may overlook this cumulative regulatory burden. As part of the preliminary manufacturer impact analysis (MIA), DOE assessed the cumulative regulatory burden by identifying and characterizing other significant product-specific regulations that could affect furnace fan manufacturers. Details of the cumulative regulatory burden assessment for the preliminary MIA are presented in chapter 12 of this TSD. DOE considered in the preliminary MIA assessment of cumulative regulatory burden the regulations presented by interested parties. DOE evaluates the impacts of the cumulative regulatory burden in subsequent phases of the manufacturer impact analysis, which will occur during the NOPR phase of this rulemaking.

2.13 EMPLOYMENT IMPACT ANALYSIS

The adoption of energy conservation standards can affect employment both directly and indirectly. Direct employment impacts are changes in the number of employees at the plants that produce the covered products, along with affiliated distribution and service companies. DOE will evaluate direct employment impacts in the MIA.

Indirect employment impacts may result from expenditures shifting between goods (the substitution effect) and changes in income and overall expenditure levels (the income effect) that occur due to standards. DOE defines indirect employment impacts from standards as net jobs eliminated or created in the general economy as a result of increased spending driven by increased product prices and reduced spending on energy.

The indirect employment impacts will be investigated in the employment impact analysis using the Pacific Northwest National Laboratory's "Impact of Sector Energy Technologies" (ImSET) model.[24] The ImSET model was developed for DOE's Office of Planning, Budget, and Analysis to estimate the employment and income effects of energy-saving technologies in buildings, industry, and transportation. Compared with simple economic multiplier approaches, ImSET allows for more complete and automated analysis of the economic impacts of energy conservation investments.

2.14 UTILITY IMPACT ANALYSIS

To estimate the impacts of potential energy conservation standards for furnace fans on the electric utility industry, DOE will use a variant of the EIA's National Energy Modeling System called NEMS-BT.[25] NEMS is a large, multi-sectoral, partial-equilibrium model of the

[24] Roop, J. M., M. J. Scott, and R. W. Schultz, ''ImSET: Impact of Sector Energy Technologies,'' PNNL–15273. Pacific Northwest National Laboratory (2005).

[25] For more information on NEMS, please refer to the U.S. Department of Energy, Energy Information Administration documentation. A useful summary is *National Energy Modeling System: An Overview 2000*, DOE/EIA-0581 (March 2000), available at: http://tonto.eia.doe.gov/ftproot/forecasting/05812000.pdf. EIA approves use of the name NEMS to describe only an official version of the model without any modification to code or data. Because this analysis entails some minor code modifications and the model is run under various policy scenarios

U.S. energy sector that EIA has developed over several years, primarily for the purpose of preparing the *AEO*. NEMS produces a widely recognized forecast for the United States through 2035 and is available to the public.

The utility impact analysis is a comparison between the NEMS-BT model results for the base case and standard cases. Outputs of the utility impact analysis usually parallel results that appear in the latest *AEO*, with some additions. The utility impact analysis reports the changes in installed capacity and generation that result from each standard level by plant type. DOE will model the anticipated energy savings impacts from potential amended energy conservation standards using NEMS-BT to generate forecasts that deviate from the *AEO* Reference Case.

NEEP stated that DOE should quantify the benefit of demand reduction in financial terms. (NEEP, No. 16 at p. 4) Adjuvant stated that DOE has not carried through the utility impact analysis to the point where it estimates the economic impact of the reduction in the need for new generation capacity on all electricity consumers – a rate impacts benefit for all ratepayers. Adjuvant stated that this is a serious shortcoming in this part of the analysis and urged the Department to estimate these impacts and make them public as part of this rulemaking. (Adjuvant, No. 9 at pp. 10-11)

DOE plans to use NEMS-BT to assess the impacts of the reduced need for new electric power plants and infrastructure projected to result from standards. In NEMS-BT, changes in power generation infrastructure affect utility revenue requirements, which in turn affect electricity prices. DOE plans to estimate the impact on electricity prices associated with each considered TSL. Although the aggregate benefits for electricity users are potentially large, there may be negative effects on some of the entities involved in electricity supply, particularly power plant providers and fuel suppliers. Because there is uncertainty about the extent to which the benefits for electricity users from reduced electricity prices would be a transfer from actors involved in electricity supply to electricity consumers, DOE has concluded that, at present, it should not give a heavy weight to this factor in its consideration of the economic justification of new or amended standards. DOE is continuing to investigate the extent to which electricity price changes projected to result from standards represent a net gain to society.

2.15 EMISSIONS ANALYSIS

In the emissions analysis, DOE estimates the reduction in power sector emissions of carbon dioxide (CO_2), nitrogen oxides (NO_x), and mercury (Hg) using the NEMS-BT computer model. In the emissions analysis, NEMS-BT is run similarly to the *AEO* NEMS, except that furnace fan energy use is reduced by the amount of energy saved (by fuel type) due to each considered standard level. The inputs of national energy savings come from the NIA spreadsheet model, while the output is the forecasted physical emissions. The net benefit of each considered

---

that are variations on EIA assumptions, DOE refers to the model by the name NEMS-BT. ("BT" refers to DOE's Building Technologies Program, under whose aegis this work is performed.)

standard level is the difference between the forecasted emissions estimated by NEMS-BT at that level and the *AEO* Reference Case.

2.15.1 Carbon Dioxide

In the absence of any Federal emissions control regulation of power plant emissions of CO_2, a DOE standard is likely to result in reductions of these emissions. The CO_2 emission reductions likely to result from a standard will be estimated using NEMS-BT and national energy savings estimates drawn from the NIA spreadsheet model. The net benefit of the standard is the difference between emissions estimated by NEMS-BT at each standard level considered and the *AEO* Reference Case. NEMS-BT tracks CO_2 emissions using a detailed module that provides results with broad coverage of all sectors and inclusion of interactive effects.

2.15.2 Sulfur Dioxide

Sulfur dioxide (SO_2) emissions from affected electric generating units (EGUs) are subject to nationwide and regional emissions cap-and-trade programs, and DOE has preliminarily determined that these programs create uncertainty about the potential standards' impact on SO_2 emissions. Title IV of the Clean Air Act sets an annual emissions cap on SO_2 for affected EGUs in the 48 contiguous States and the District of Columbia (D.C.). SO_2 emissions from 28 eastern States and D.C. are also limited under the Clean Air Interstate Rule (CAIR, 70 Fed. Reg. 25162 (May 12, 2005)), which created an allowance-based trading program. Although CAIR has been remanded to EPA by the U.S. Court of Appeals for the District of Columbia Circuit (D.C. Circuit), see *North Carolina v. EPA*, 550 F.3d 1176 (D.C. Cir. 2008), it remained in effect temporarily, consistent with the D.C. Circuit's earlier opinion in *North Carolina v. EPA*, 531 F.3d 896 (D.C. Cir. 2008). On July 6, 2011 EPA issued a replacement for CAIR, the Cross-State Air Pollution Rule. 76 FR 48208 (August 8, 2011). (See http://www.epa.gov/crossstaterule/). On December 30, 2011, however, the D.C. Circuit stayed the new rules while a panel of judges reviews them and told EPA to continue enforcing CAIR (see *EME Homer City Generation v. EPA*, No. 11-1302, Order at *2 (D.C. Cir. Dec. 30, 2011)).

The attainment of emissions caps is typically flexible among EGUs and is enforced through the use of emissions allowances and tradable permits. Under existing EPA regulations, any excess SO_2 emissions allowances resulting from the lower electricity demand caused by the adoption of an energy conservation standard could be used to permit offsetting increases in SO_2 emissions by any regulated EGU. However, if the standard resulted in a permanent increase in the quantity of unused emissions allowances, there would be an overall reduction in SO_2 emissions from the standards. While there remains some uncertainty about the ultimate effects of energy conservation standards on SO_2 emissions covered by the existing cap-and-trade system, the NEMS-BT modeling system that DOE uses to forecast emissions reductions currently indicates that no physical reductions in power sector emissions would occur for SO_2. DOE acknowledges, however, that even though there is a cap on SO_2 emissions and uncertainty whether efficiency standards would reduce SO_2 emissions, it is possible that standards could reduce the compliance cost by reducing demand for SO_2 allowances.

2.15.3 Nitrogen Oxides

Under CAIR, there is a cap on NO_X emissions in 28 eastern States and the District of Columbia. All these States and D.C. have elected to reduce their NO_X emissions by participating in cap-and-trade programs for EGUs. Therefore, energy conservation standards may have little or no physical effect on these emissions in the 28 eastern States and D.C. for the same reasons that they may have little or no physical effect on SO_2 emissions. However, standards would be expected to reduce NO_X emissions in the 22 States not affected by CAIR. DOE is using the NEMS-BT to estimate NO_X emissions reductions from possible standards in the States where emissions are not capped.

2.15.4 Mercury

In the absence of caps, a DOE energy conservation standard could reduce Hg emissions, and DOE plans to use NEMS-BT to estimate these emission reductions. On February 16, 2012, EPA published national emissions standards for hazardous air pollutants (NESHAPs) for mercury and certain other pollutants emitted from coal and oil-fired EGUs. 77 FR 9304 (Feb. 16, 2012). The NESHAPs do not include a trading program and, as such, DOE's energy conservation standards would likely reduce Hg emissions. For the emissions analysis for this rulemaking, DOE plans to estimate mercury emissions reductions using NEMS-BT based on *AEO2011*, which does not incorporate the NESHAPs. DOE expects that future versions of the NEMS-BT model will reflect the implementation of the NESHAPs.

2.15.5 Particulate Matter

DOE acknowledges that particulate matter (PM) exposure can impact human health. Power plant emissions can have either direct or indirect impacts on PM. A portion of the pollutants emitted by a power plant is in the form of particulates as they leave the smoke stack. These are direct, or primary, PM emissions. However, the great majority of PM emissions associated with power plants are in the form of secondary sulfates, which are produced at a significant distance from power plants by complex atmospheric chemical reactions that often involve the gaseous (non-particulate) emissions of power plants, mainly SO_2 and NO_x. The quantity of the secondary sulfates produced is determined by a very complex set of factors including the atmospheric quantities of SO_2 and NO_x and other atmospheric constituents and conditions. Because these highly complex chemical reactions produce PM composed of different constituents from different sources, EPA does not distinguish direct PM emissions from power plants from the secondary sulfate particulates in its ambient air quality requirements, PM monitoring of ambient air quality, or PM emissions inventories. For these reasons, it is not currently possible to determine how the amended standard impacts either direct or indirect PM emissions. Therefore, DOE is not planning to assess the impact of these standards on PM emissions. Further, as described previously, it is uncertain whether efficiency standards will result in a net decrease in power plant emissions of SO_2, which are now largely regulated by cap-and-trade systems.

2.16 MONETIZATION OF EMISSIONS REDUCTION BENEFITS

DOE plans to estimate the monetary benefits likely to result from the reduced emissions of CO_2 and NO_X that are expected to result from each of the standard levels considered.

In order to estimate the monetary value of benefits resulting from reduced emissions of CO_2 emissions, DOE uses the most current Social Cost of Carbon (SCC) values developed or agreed to by interagency reviews. The SCC is intended to be a monetary measure of the incremental damage resulting from greenhouse gas (GHG) emissions, including, but not limited to, net agricultural productivity loss, human health effects, property damage from sea level rise, and changes in ecosystem services. Any effort to quantify and to monetize the harms associated with climate change will raise serious questions of science, economics, and ethics. But with full regard for the limits of both quantification and monetization, the SCC can be used to provide estimates of the social benefits of reductions in GHG emissions.

At the time of this analysis, the most recent interagency estimates of the potential global benefits resulting from reduced CO_2 emissions in 2010, expressed in 2010$, were $4.9, $22.3, $36.5, and $67.6 per metric ton avoided. For emission reductions that occur in later years, these values grow in real terms over time. Additionally, the interagency group determined that a range of values from 7 percent to 23 percent should be used to adjust the global SCC to calculate domestic effects, although DOE will give preference to consideration of the global benefits of reducing CO_2 emissions. To calculate a present value of the stream of monetary values, DOE will discount the values in each of the four cases using the discount rates that had been used to obtain the SCC values in each case.

DOE recognizes that scientific and economic knowledge continues to evolve rapidly as to the contribution of CO_2 and other GHG to changes in the future global climate and the potential resulting damages to the world economy. Thus, these values are subject to change.

DOE also will estimate the potential monetary benefit of reduced NO_X emissions resulting from the standard levels it considers. Available estimates suggest a very wide range of monetary values for NO_X emissions, ranging from $370 per ton to $3,800 per ton of NO_X from stationary sources, measured in 2001$ (equivalent to a range of $450 to $4,623 per ton in 2010$).[26] In accordance with U.S. Office of Management and Budget (OMB) guidance, DOE will conduct two calculations of the monetary benefits derived using each of the economic values used for NO_x, one using a real discount rate of 3 percent and another using a real discount rate of 7 percent.[27]

DOE does not plan to monetize estimates of Hg reduction in this rulemaking. DOE is aware of multiple agency efforts to determine the appropriate range of values used in evaluating

---

[26] For additional information, refer to U.S. Office of Management and Budget, Office of Information and Regulatory Affairs, *2006 Report to Congress on the Costs and Benefits of Federal Regulations and Unfunded Mandates on State, Local, and Tribal Entities* (Available at: http://www.whitehouse.gov/sites/default/files/omb/assets/omb/inforeg/2006_cb/2006_cb_final_report.pdf).
[27] OMB, Circular A-4: Regulatory Analysis (Sept. 17, 2003).

the potential economic benefits of reduced Hg emissions. DOE has decided to await further guidance regarding consistent valuation and reporting of Hg emissions before it once again monetizes Hg in its rulemakings.

Adjuvant supported the monetization of carbon emissions and stated that the range of values is reasonable. (Adjuvant, No. 9 at p. 11) Ingersoll Rand stated that the ranges of monetary values on CO_2 and NOx are so wide as to be of little utility in selecting appropriate values for use in an analysis representing the situation in the United States over the time span that the analysis should cover. (Ingersoll Rand, No. 25 at p. 5) DOE acknowledges that the market value of future CO_2 emissions reductions is uncertain, and for this reason it uses a wide range of potential values, as described above.

2.17 REGULATORY IMPACT ANALYSIS

In the NOPR stage, DOE will prepare a regulatory impact analysis (RIA) pursuant to Executive Order 12866, "Regulatory Planning and Review," 58 FR 51735 (Oct. 4, 1993). The RIA evaluates potential non-regulatory policy alternatives, comparing the costs and benefits of each to those of the proposed standards. The RIA is subject to review under the Executive Order by the Office of Information and Regulatory Affairs (OIRA) at the Office of Management and Budget.

DOE recognizes that non-regulatory policy alternatives can substantially affect energy efficiency or reduce energy consumption. DOE will base its assessment on the actual impacts of any such initiatives to date, but also will consider information presented by interested parties regarding the potential future impacts of current initiatives.